THE WATER SUPPLY

OF THE CITY OF NEW YORK

DEPARTMENT OF WATER SUPPLY,
GAS AND ELECTRICITY

JOSEPH GOODMAN
Commissioner

DECEMBER, 1937

J. Perrotta

THE WATER SUPPLY

OF THE CITY OF NEW YORK

DEPARTMENT OF WATER SUPPLY,
GAS AND ELECTRICITY

JOSEPH GOODMAN
Commissioner

DECEMBER, 1937

AVERY ARCHITECTURAL AND FINE ARTS LIBRARY
GIFT OF SEYMOUR B. DURST OLD YORK LIBRARY

HERALD-NATHAN PRESS, INC.
460 W. 34TH STREET, N. Y.
271

CONTENTS

	Page
Historical	5
Watersheds, Reservoirs and Aqueducts	8
Croton System	10
Old Croton Aqueduct	12
New Croton Aqueduct	12
Croton Lake Pumping Plant	14
Bronx and Byram Systems	16
Catskill System	16
Shandaken Tunnel	18
Gilboa Dam	20
Schoharie Reservoir	20
Ashokan Reservoir	20
Kensico Reservoir	22
Hillview Reservoir	24
Silver Lake Reservoir	26
Catskill Aqueduct	26
City Tunnel No. 1	30
City Tunnel No. 2	32
Ridgewood System	32
Queens System	36
Development of Additional Supply from Long Island	36
Richmond System	36
Utilization of Present Sources of Water Supply	38
Quality of Water	40
Distribution Systems	44
High Pressure Fire Service	50
Consumption and Waste of Water	51
Private Water Companies	56
Supply to Communities Outside of New York City	56
Water Revenue	58
Financial	59
Administrative Officers	59
Table of Distributing Mains in Use at End of 1936	60
Table of Storage Reservoirs in Watersheds	61
Table of Main Aqueducts and Pipe Lines	62
Table of Distribution Reservoirs and Pipe Lines	63
Table of Population and Consumption of Water	64

Digitized by the Internet Archive
in 2014

https://archive.org/details/watersupplyofcit00newy_0

THE WATER SUPPLY
OF THE CITY OF NEW YORK

HISTORICAL

The present City of New York is the result of the consolidation in 1898 of various communities located in the vicinity of New York Harbor, which are now included in the boroughs of Manhattan, the Bronx, Brooklyn, Queens and Richmond. Their water supplies were developed without regard to the present city limits and it was not until 1917 that New York was served by a system planned for the city as a whole.

The borough of Manhattan, constituting the old City of New York, had until 1842, no general water supply system, although its population at that time amounted to over 300,000. The early settlers of Manhattan Island obtained water for domestic purposes from shallow wells which were at first constructed by individual enterprise. The first public well was dug in front of the old fort at Bowling Green on or about the year 1677. Additional public wells were sunk in the streets from time to time, as required, the city bearing part of the expense and part having been assessed on the property benefited. In 1776, when the population reached 22,000, a reservoir was constructed on the east side of Broadway between Pearl and White Streets. Water was pumped from wells sunk near the famous "Collect" Pond east of the reservoir, and from the pond itself, and was distributed through hollow logs laid in the principal streets. In 1800 the Manhattan Company (now the Manhattan Bank) sunk a well at Reade and Centre Streets, pumped water therefrom into a reservoir on Chambers Street and distributed it thence through wooden mains to a portion of the community which, at that time, consisted of about 60,000 inhabitants. The maximum amount supplied by this company was 700,000 gallons a day. In 1830 a tank for fire protection was constructed by the City at 13th Street and Broadway. This tank was filled by pumping from a well sunk for the purpose, and the contents distributed through two lines of 12-inch cast iron pipe, one extending down The Bowery to Chatham Square and the other through Broadway and Canal Street. This was the beginning of the public water works of New York City. The well was 16 feet in diameter and 112 feet in depth, 98 feet of which was excavated through solid rock. At the bottom of the well two galleries extended, 6 feet by 4 feet, one 25 feet, and the other 75 feet in length. The daily yield of the well amounted to 21,000 gallons and was pumped by a 12 H.P. steam engine into a cast iron tank of 43 feet diameter and 20½ feet height, enclosed in an octagonal stone building.

As the population of the City increased, the well waters became brackish or polluted with organic matter and insufficient in quantity. To meet ordinary domestic needs, main dependence was upon cisterns supplied from rain caught upon the roofs; water secured from a few springs in the upper part of the City was sold from large casks at two cents a pail.

After entertaining numerous schemes for a suitable source of supply, among which were Rye Pond, Bronx and Byram Rivers in Westchester County, Passaic River in New Jersey and artesian wells on Manhattan Island, it was decided to build an aqueduct from the Croton River to the City, to be supplied by one storage reservoir; this aqueduct (known today as the Old Croton Aqueduct), with a capacity of 90 m.g.d., was placed in service in 1842, its completion having been expedited by the great conflagration of 1835. This was an event of great importance in the history of older New York. The distribution reservoirs were at Forty-second Street (abandoned in 1890), and in Central Park, south of Eighty-sixth Street (abandoned in 1925). In the drought of 1869-70 the right was secured to draw down six of the lakes and ponds in the Croton watershed. Boyd's Corners Reservoir was then constructed in 1873 and Middle Branch in 1878. In due course the old Croton aqueduct became inadequate, and in 1883 a commission was formed to build a second one from the Croton watershed, as well as additional storage reservoirs in that watershed. The second aqueduct, known as the New Croton Aqueduct, was under construction from 1885 to 1893 (though it was used as early as 1890), and has a capacity of 285 m.g.d.

West Bronx was annexed to the old City of New York in 1874 and East Bronx in 1895. The system of the New York and Westchester Water Company which supplied the villages of Williamsbridge and Wakefield and the towns of Westchester and Pelham from the Hutchinson River was acquired by the City in 1903; the Upper New York City Water Company which supplied the village of Eastchester was acquired by the city in 1905. A municipal supply from the Bronx and Byram Rivers was made available in 1895. The waters from these watersheds, yielding about 20 m.g.d., were originally delivered into a 48-inch cast iron pipe line over fifteen miles long, leading from the former Kensico Lake to the Williamsbridge reservoir (abandoned in 1934), in the Bronx. In 1916 this lake was merged in the new Kensico reservoir, and at that point the waters from the Bronx and Byram watersheds became merged with the new Catskill supply.

The former City of Brooklyn, like the former City of New York, did not develop a public water supply system until its population had reached nearly 300,000, the use of local wells and cisterns being the only sources of supply prior to 1859. In that year the city began delivering water collected on the south side of Long Island into its distribution system, pumping this water at the Ridgewood north side pumping station. The original works ran easterly to the Hempstead Valley. Later they were

extended to Massapequa, Long Island, and the large Milburn and the Ridgewood South Side pumping stations constructed.

For the Borough of Queens no municipal waterworks of magnitude has been constructed. Prior to 1913 the First Ward was served by three local municipal pumping stations and by private water companies. Between 1913 and 1917 it was served largely from the Brooklyn watershed. The Third Ward, prior to 1917, was served by two municipal pumping stations, while the Second, Fourth and Fifth Wards were supplied by private water companies, their sources of supply being ground water collected by means of driven wells.

On April 20, 1922, that part of the plant of the Citizens Water Supply Company supplying the Second Ward was acquired through condemnation by the City, and at present is municipally operated, and on April 15, 1931, the Fifth Ward plant of the Long Island Water Corporation was acquired by purchase. The Citizens Water Supply Company was incorporated June 1, 1893, and began to supply water the following year; the Long Island Water Corporation was incorporated March 27, 1884, and its first water works system at Far Rockaway was constructed in 1885.

Prior to 1917 the Borough of Richmond was dependent for its supply on ground water from wells. Until 1909, except as to Tottenville, it was served by private water companies. The principal of these companies, the Staten Island Water Supply Company, incorporated September 19, 1878, and the Crystal Water Supply Company, incorporated March 16, 1883, were in 1909 acquired by the City. The last of the private companies in this borough (the South Shore Water Works Company, which was originally incorporated on July 10, 1889), was acquired by the City in 1917.

Some 36 years ago, the necessity was foreseen of providing a large additional water supply for the use of Greater New York and in 1902 definite steps were taken to formulate and execute such a plan. In that year a commission of engineers was appointed which, after careful study, recommended that the city go to the Catskills for additional water. In 1905 the Board of Water Supply—not to be confused with the Department of Water Supply, Gas and Electricity—was created by act of the Legislature, and proceeded forthwith to plan and construct the works for impounding the waters of the Esopus, one of the four watersheds in the Catskills, upon which the city had planned to draw, and for delivering such waters throughout New York City. This monumental work, commonly known as the Catskill system, was successfully completed and turned over to the Department of Water Supply, Gas and Electricity for maintenance and operation in 1917. The second stage of the Catskill development, which involved the construction of the Schoharie reservoir and Shandaken tunnel, was finished and turned over to the Department on June 1, 1928. The Schoharie supply was used on and after February 3, 1924, when the tunnel was

opened. Under a resolution of the Board of Estimate and Apportionment, adopted June 17, 1921, the Board of Water Supply was empowered to investigate sources of additional supply for the City and the more adequate extension of existing and future water supplies.

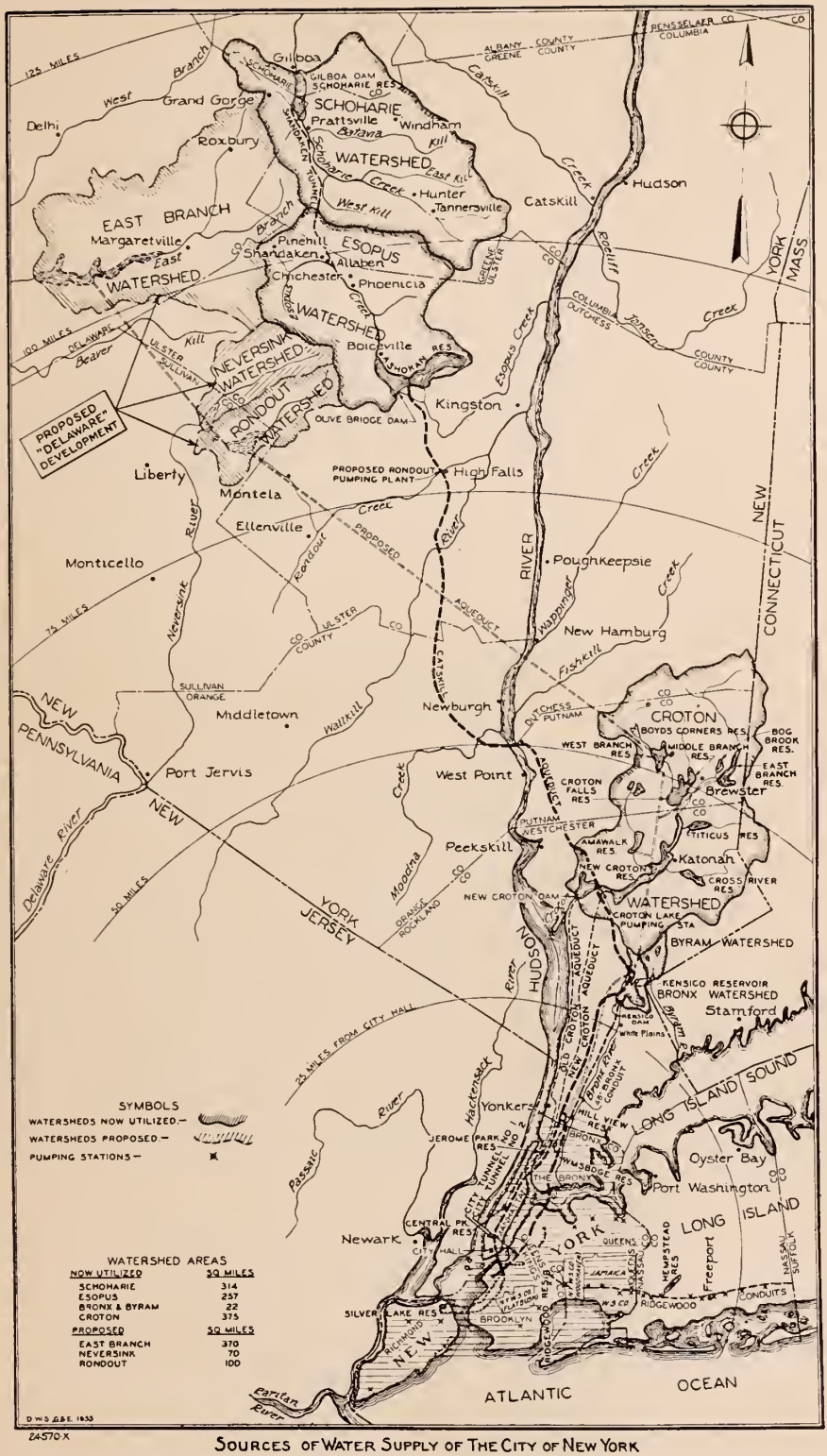
In 1927 the Board of Water Supply submitted to the Board of Estimate and Apportionment a plan recommending the upper portion of the Rondout watershed and the tributaries of the Delaware River lying wholly in the State of New York as the most available and economical sources of new water supply for New York City. The project was approved by the Board of Estimate and Apportionment in 1928, and by the Water Power and Control Commission in 1929, but was held back because of action brought by the State of New Jersey in the U. S. Supreme Court, to enjoin the City and State of New York from using the waters of any of the tributaries of the Delaware River. In May, 1931, the U. S. Supreme Court upheld the right of New York City to augment its water supply from the headwaters of the Delaware River. The city, however, was permitted to divert at the present time only 440,000,000 gallons daily from the tributaries of the Delaware River instead of the 600,000,000 gallons planned. It is estimated that the upper portion of the Rondout watershed will yield 100,000,000 gallons daily. The combined watersheds will therefore yield 540,000,000 gallons daily. The upper Rondout and Delaware watershed development, including the proposed aqueduct to the city, is generally referred to as the Delaware system.

It is proposed to develop the upper Rondout and tributaries of the Delaware River in two or three stages, and it will require about eight years to develop the first stage and deliver an additional supply of water to the city. Actual work upon this development was started March 21, 1937.

Gratifying results have been obtained in reducing consumption to aid the City in meeting the water supply demands until the advent of the Delaware water by elimination of waste through holding pressures within reasonable limits, by carrying on a systematic survey to locate and stop leaks in the distribution mains and appurtenances and house services outside of buildings, and by systematic house-to-house inspection to locate leaky fixtures within buildings and compelling repairs to be made to same.

WATERSHEDS, RESERVOIRS AND AQUEDUCTS

The municipality now has available as sources of supply (1) Schoharie and Esopus Creeks in the Catskills where water is collected in the Schoharie and Ashokan Reservoirs, (2) Bronx and Byram Rivers in Westchester County, where the water is stored in Byram and Wampus ponds and in the enlarged Kensico reservoir, now part of the Catskill system, (3) Croton River in Putnam and Westchester Counties, where the water



SOURCES OF WATER SUPPLY OF THE CITY OF NEW YORK
SHOWING WATERSHEDS AND AQUEDUCTS

is collected in 12 reservoirs and six controlled lakes, (4) Brooklyn and Ridgewood watersheds on the south side of Long Island, where water is obtained from small streams, infiltration galleries and driven wells, (5) Borough of Queens, where water is obtained from driven wells, (6) Borough of Richmond, where water is obtained from driven wells.

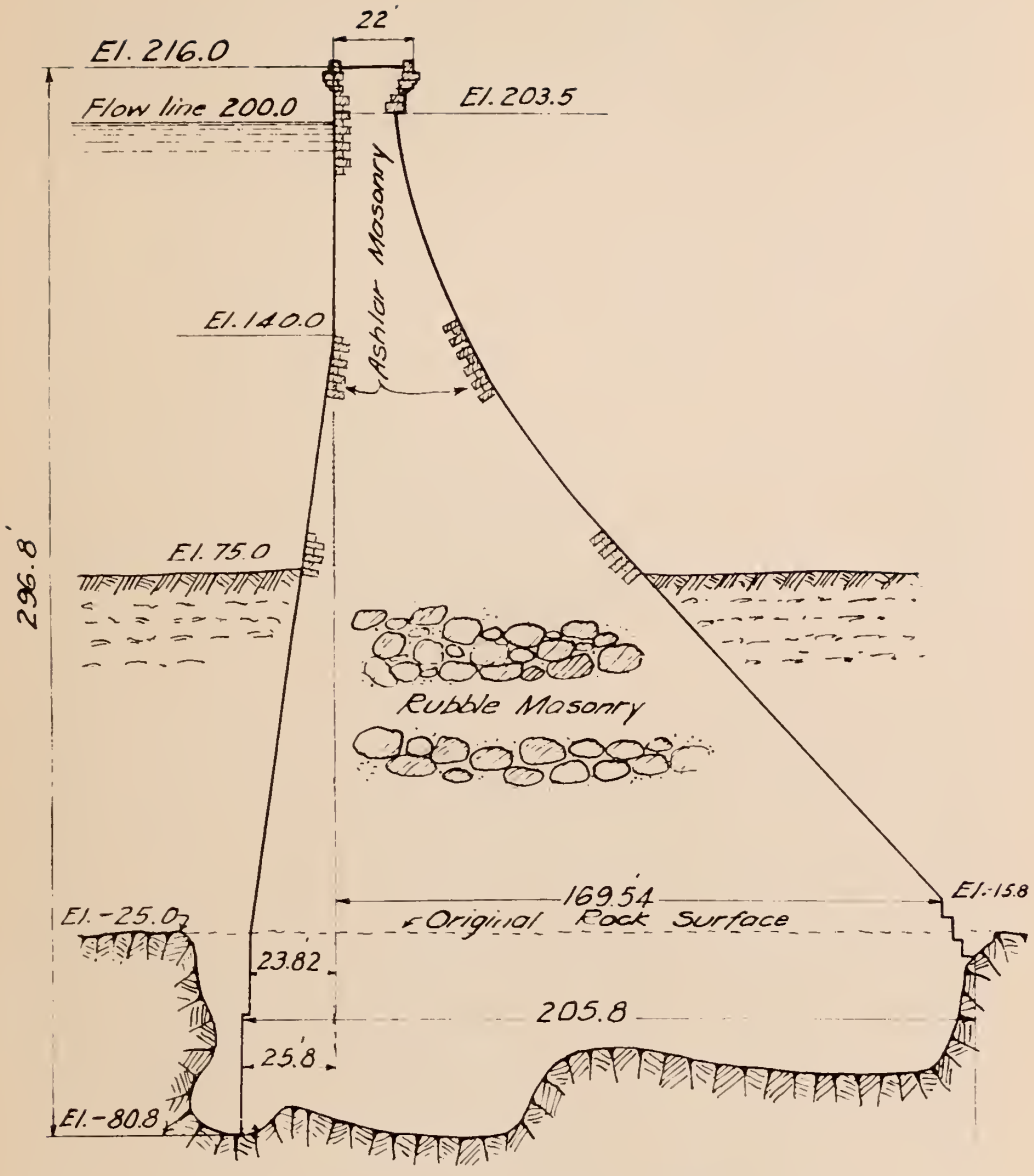
Brief descriptions of the various systems follow:

CROTON SYSTEM

The Croton River is formed by three branches, known respectively as the East, Middle and West Branch, which rise in the southern part of Dutchess County, flow in a southerly direction through Putnam County and unite near its southerly boundary. The river continues in a southwesterly direction across Westchester County to the Hudson River, into which it empties at Croton Point, 22 miles from the northerly limits of New York City. The principal tributaries of the Croton are the Titicus, Cross, Kisco and Muscoot Rivers.

The watershed extends about 33 miles north and south and eleven miles east and west; it lies almost entirely within the State of New York, only a small portion being in Connecticut. Its area is 375 square miles above the new Croton dam, and it may be relied upon to yield at least 300 m.g.d., the yield in the past 68 years having averaged 400 m.g.d. Its waters are collected through twelve storage reservoirs and six controlled lakes having an aggregate storage capacity of 103,100 m.g. The lowest and largest of the reservoirs is Croton Lake, which is formed by the new Croton dam; it is about 20 miles in length and has an available storage capacity of 33,885 m.g. The population on the watershed is about 50,000, mainly concentrated in several small towns and villages. The watershed is very hilly. The surface soil is composed principally of sand and gravel; clay, hardpan and peat are found in a few localities, but only to a very limited extent. The rock formation consists generally of gneiss. Strata of limestone, some micaceous and talcose slates, veins of granite serpentine and iron ore occur in a few places. The Croton water is a soft water, although not so soft as the Catskill water. To protect the supply a margin about 300 feet has been acquired by the city around all reservoirs and along some of the tributary streams.

The new Croton reservoir was constructed between 1892 and 1905 at a cost of approximately $17,000,000, including land, the cost of the dam itself having been close to $7,000,000. The dam is built across the valley of the Croton River, three miles above the point where it empties into the Hudson River. Including a curved spillway 1,000 feet long, it has a total length of 2,168 feet. It is founded upon bed rocks of gneiss and limestone. The maximum width at the base is 206 feet, the maximum



NEW CROTON DAM

MAXIMUM SECTION

SCALE: 1" = 40'

Note:—Elevations refer to Croton datum which is 0.94 ft. below mean sea level at Sandy Hook.

height 296.8 feet, and minimum thickness at top 18 feet. With the exception of 128 feet of earth section with masonry core, the entire dam is partly of "cyclopean," but mainly of rubble masonry, faced above the backfilling with ashlar masonry. The spillway of the dam is at elevation 199.06 feet; two-foot permanent flashboards are set on top of the spillway.

Old Croton Aqueduct

The Old Croton aqueduct was constructed in 1837-1842. It begins at Croton Lake, follows the Croton River to a point near its mouth, and then the Hudson river to Yonkers. Here it crosses the Sawmill river and Tibbets Brook, and continues to the Harlem river, which it crosses on Highbridge, thence to the receiving reservoir in Central Park. The standard section is of horse-shoe shape containing 53.34 square feet. It is founded on concrete 3 to 12 inches thick; the side walls are of rubble masonry. Sides and bottom are lined with 4 inches of brick, and the top arches of 8 inches of brickwork. Valleys, as a rule, are crossed on earth embankmkents with dry rubble walls. The grade in general is 0.021 feet per 100. Harlem River is crossed by means of a 90 inch steel pipe, which is carried by a masonry structure with central steel-arch span, known as Highbridge. Manhattan Valley is crossed by means of two lines of 36 inch, one 48 inch, and one 60 inch cast iron pipe.

While repairs to this aqueduct have been made from time to time, and some short sections built on embankments have been reconstructed, it is still in generally good condition, but is capable of delivering without excessive leakage only about 45 m.g.d., or about one-half of the full capacity for which it was originally designed.

Practically all the Croton water reaching Manhattan is carried to the gatehouse at 135th Street and Convent Avenue, except that taken from the New Croton Aqueduct at the 179th Street pumping station. From the 135th Street gatehouse all Croton water goes by gravity into the mains either directly or through the distributing reservoirs in Central Park, except that which is sent to the 98th Street pumping station.

New Croton Aqueduct

The New Croton Aqueduct was constructed in 1885-1891. It consists essentially of three parts:

1st—A masonry conduit from the inlet gatehouse which is located near the Old Croton Dam, and three miles north of the new Croton Dam, to Mosholu Avenue near the Jerome Park distributing reservoir, a distance of 23.92 miles. The invert at the gatehouse is 60 feet below the elevation

Croton Dam and Spillway, with flood waters discharging over the waste weir.

of the spillway at the New Croton Dam, the grade thence being uniformly 0.7 feet per mile, except for the inverted siphon under Gould's Swamp near Tarrytown. The nominal capacity of this stretch is 285 m.g.d. This portion of the aqueduct is of horse-shoe section, except the Gould's Swamp siphon, which is circular, 14 feet 3 inches internal diameter and 1,135 feet long. It was constructed mainly in tunnel and follows a southerly direction along Pocantico River, Sawmill River and Tibbets Brook. The aqueduct is lined with brickwork, varying from 12 to 24 inches for the sides and arch, and from 8 to 24 inches for the invert, according to external pressure; the invert was laid on a foundation of concrete and rubble. The space between the sides and roof of the tunnel excavation and the brick lining was filled with rubble masonry to a level of four feet above the crown of the intrados of the arch.

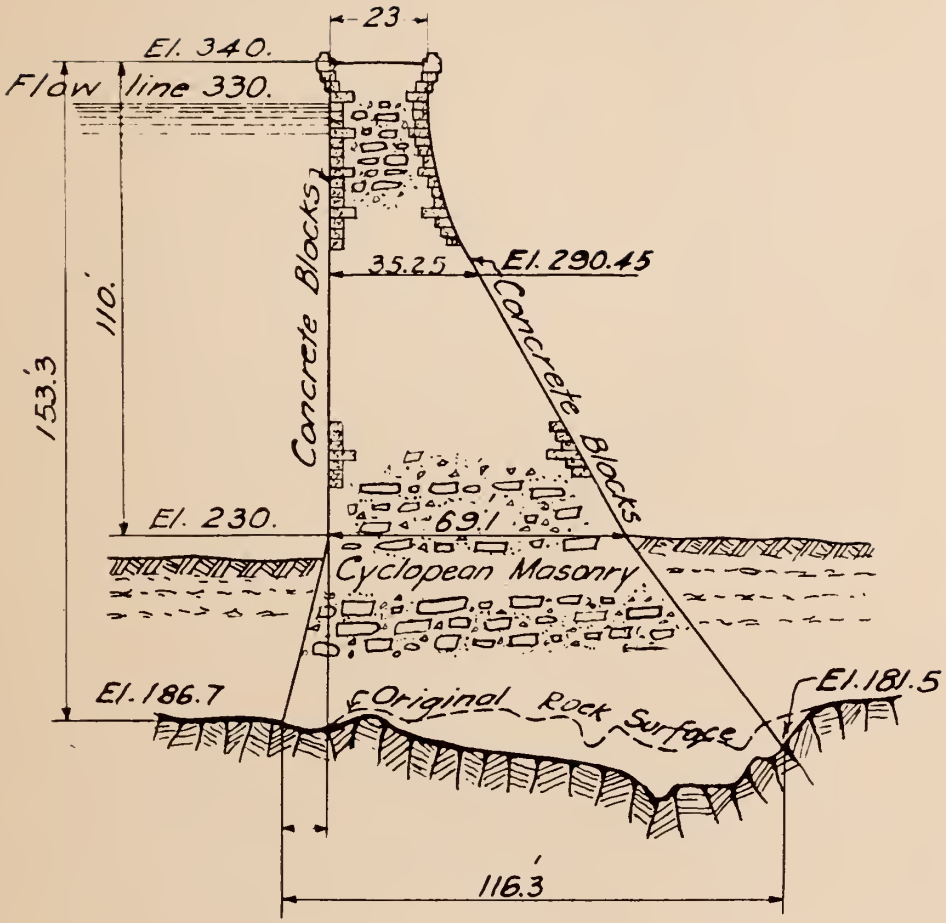
2nd—A masonry conduit under pressure from Mosholu Avenue to gatehouse on Manhattan Island at 135th Street and Convent Avenue. This portion forms a long inverted siphon; its cross-section is circular, the inner diameter being 12 feet 3 inches, except in the tunnel under the Harlem River, where it was reduced to 10½ feet to increase the velocity of current in order to prevent deposit of silt. To avoid heavy land damages the aqueduct at Mosholu Avenue was depressed 115.64 feet by an incline having a 10 per cent grade, and continued on a grade of 0.7 feet per mile, to a point within 1,100 feet of the Harlem River. Here the aqueduct was lowered 127.5 feet on a 15 per cent grade, then 172 feet, passing under the Harlem River 300 feet below high water, descending on a 1 per cent grade. On the Manhattan side the conduit ascends from the shaft to the gatehouse at a grade of 0.65 feet per 1,000 feet. The nominal carrying capacity of this stretch of the aqueduct is 250 m.g.d., the difference being allowed for the water taken out of Jerome Park Reservoir for the Bronx supply; this capacity is further reduced by the additional head maintained at the 135th Street gatehouse.

3rd—Pipe lines from 135th Street Gatehouse. From this point, five lines of steel mains, two 60 inches, and three 48 inches in diameter, are laid to 133rd Street and Convent Avenue, where they connect with seven lines of 48 inch cast iron pipe. Three of these mains are used for conveying water to Central Park Reservoir; the other four mains connect with the distributing system at various points.

Croton Lake Pumping Plant

The pumping plant installed at the Croton Lake gatehouse is comprised of three motor-driven centrifugal units each of 60 m.g.d. capacity.

The plant, which has been in operation since March 15, 1932 is designed to lift water from the Croton Lake gate house, discharging it through a 72-inch steel line approximately 1,600 feet long, into the Catskill Aque-



CROSS RIVER DAM

MAXIMUM SECTION

SCALE: 1" = 40'

Note:—Elevations refer to Croton datum, which is 0.94 ft. below mean sea level at Sandy Hook.

duct, at a level of about 170 feet above that of the surface of Croton Lake. The station is not operated continuously, but only over such periods as may be necessary to equalize the difference in the quantity of stored water in the Catskill and Croton watersheds, thus providing greater flexibility in the operation of the City's water supply, or to permit an increased delivery of water through the Catskill aqueduct to Kensico reservoir.

BRONX AND BYRAM SYSTEMS

Work on the development of the Bronx River and Byram River watersheds, covering 13.33 and 8.66 square miles respectively, was commenced in 1880, but owing to long negotiations with riparian owners on the Byram River in Connecticut, the entire construction was not completed until 1897, although part of the supply was made available in 1884.

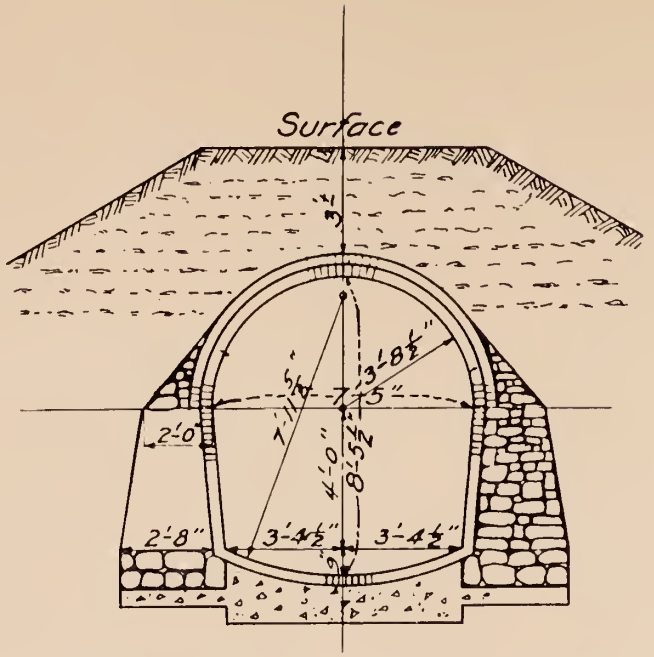
A small diverting dam, about 1100 feet north of the Connecticut State line, was constructed on the Byram River (the outlet of Byram Lake), just below the point where the Wampus River (the outlet of Wampus Pond), unites with it. From this dam the waters of the Byram and Wampus rivers are led into the Bronx watershed through a tunnel and open channel a distance of 3,800 feet.

The original Kensico dam, which was constructed across the Bronx River near the Kensico station of the Harlem Railroad, has been replaced by the present Kensico Dam. The run-off of the Bronx and Byram watersheds is merged with the Catskill water stored in Kensico Reservoir.

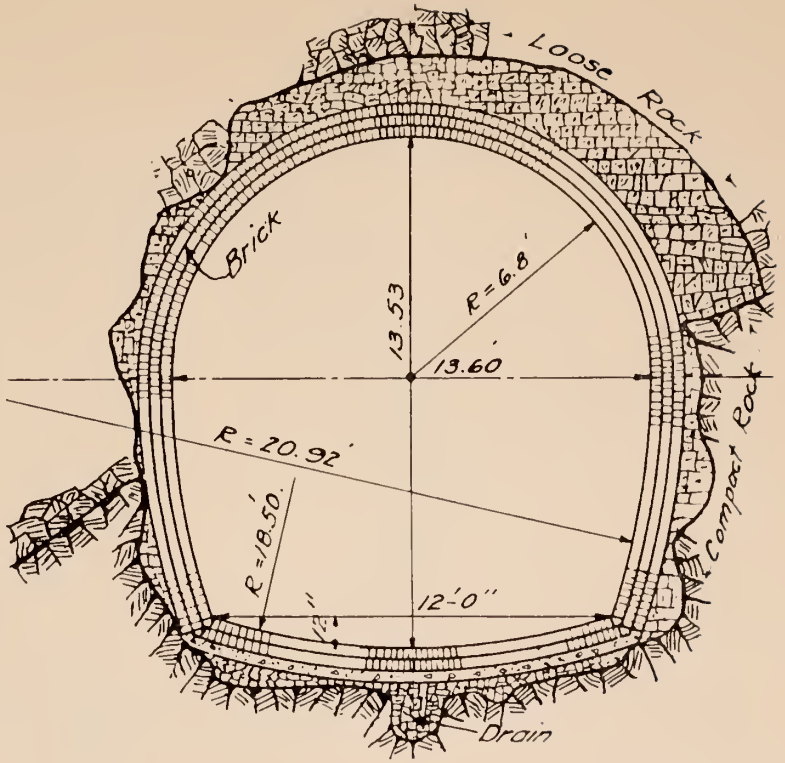
A line of 48-inch cast iron pipe, 15.2 miles in length, which was laid from the original Kensico Dam to the Williamsbridge distributing reservoir, is still in use. The inflow into this pipe line is now controlled at the new Kensico Dam. Williamsbridge reservoir was abandoned in 1934. The pipeline now connects directly with the Bronx distributing system, but is used chiefly for the purpose of furnishing water to municipalities along the line.

CATSKILL SYSTEM

Catskill water has its origin in the Esopus and Schoharie watersheds. These watersheds, occupying the central and eastern portions of the Catskill Mountains, collect the stream flow from the mountains of sparsely populated areas which they embrace. The Esopus watershed, draining naturally into the Hudson River, has an area of 257 square miles. The Schoharie watershed, draining to the north into the Mohawk River, has an area of 314 square miles. The combined drainage area of these two sources is therefore 571 square miles, and it is conservatively estimated that even during a series of extraordinary dry years, at least 500 m.g. of water daily can be drawn. The rock formations included within the Esopus



OLD CROTON AQUEDUCT



NEW CROTON AQUEDUCT

GRADE TUNNEL

IN COMPACT AND IN LOOSE ROCK

SCALE - $\frac{1}{4}$" = 1'-0"

and Schoharie watersheds are of sandstone and shale, and the water, in consequence, is of an unusual degree of softness. The greater part of the water from these two drainage areas is stored in the Ashokan Reservoir, the balance being held in the Schoharie Reservoir.

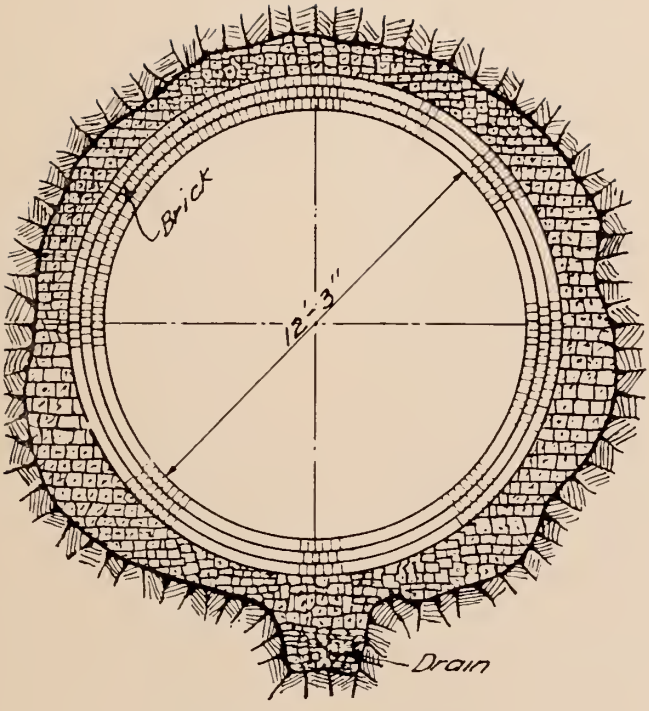
Schoharie Creek lies north of the Esopus, in the heart and higher sections of the Catskill Mountains. Gilboa Dam, built across the creek at Gilboa in Greene County, is located about four miles northeast from the Grand Gorge Station of the Ulster and Delaware Railroad. It is 120 miles in an air line north of the City Hall, and 35 miles west of the Hudson River. The tributaries have their source at elevations of nearly 2,000 feet in the localities of Hunter, Windham, Prattsville and Grand Gorge in Greene, Delaware and Schoharie Counties. The watershed is similar in character to the Esopus, chiefly steep mountains of shale and sandstone, which are covered with wild forest growth. These streams are flashy, there being large freshets in the spring with very little flow during the summer months. Because of this steep and rocky character, the flow in the stream is a large proportion of the rainfall.

While the Esopus flows out of the Catskills through the southerly gateway toward Kingston and the Hudson River, the Schoharie flows out through the northerly portals to the Mohawk River near Amsterdam. It lies at a sufficiently high elevation to enable the flow to be intercepted by a dam at Gilboa, reversing the direction and sending the water through an 18-mile tunnel under the intervening Shandaken Mountain Range into Esopus Creek at Allaben in Ulster County. The water thus diverted joins the water of the Esopus and finds its way for 15 miles into the Ashokan Reservoir, where it is available for delivery to the City through the main Catskill Aqueduct.

Shandaken Tunnel

The contract for the construction of the Shandaken Tunnel was awarded on November 9, 1917, for $12,138,738.

The intake is located about 3½ miles north of the Village of Prattsville. From here the tunnel extends in a general southeasterly direction until just south of the Village of Allaben, where it discharges into the Esopus Creek. The tunnel is horse-shoe shaped in section, concrete lined, with inside dimensions of 11 feet 6 inches in height by 10 feet 3 inches in width, and provided for a uniform slope of 4.4 feet per mile, except for the northerly 3½ miles, which is depressed, making this portion a pressure tunnel. Seven intermediate construction shafts were sunk, the aggregate depth of shaft being 3,238 linear feet, the maximum depth of a single shaft being 630 feet. The minimum distance between shafts is 1.3 miles, the maximum 2.7 miles. All shafts are circular and concrete lined. The upper



NEW CROTON AQUEDUCT

PRESSURE TUNNEL

SCALE: $\frac{1}{4}$" = 1'-0"

portion of the intake shaft is so constructed that it acts as a Venturi Meter and the building over this shaft contains the control gates and the keeper's residence.

Gilboa Dam

The Gilboa Dam is composed of two parts—an overfall masonry portion about 1,300 feet in length and having a maximum height of about 160 feet with the crest at elevation 1130 feet above sea-level, and an earth section at elevation 1150 feet, with core-wall, approximately 1,000 feet long. Along the downstream toe of the dam there is a channel for collecting and conveying the overflow flood waters into the present channel of Schoharie Creek below the dam.

Schoharie Reservoir

The Schoharie Reservoir formed by Gilboa dam serves both as a diverting and as a storage reservoir. It stores 19,583 million gallons, so that a large part of the storage for the Schoharie has been provided in the Ashokan Reservoir. It holds only 0.14 of the amount of the total flow of the Schoharie for an average year, while the Ashokan holds 1.03 times the flow of Esopus Creek. The tunnel was therefore built large enough so that in times of plenty the water can be delivered through to Ashokan at a rate of 650 million gallons a day, more than twice the normal rate of contemplated draft from Schoharie.

The reservoir is approximately five miles long and about one mile in maximum width, reaching from Gilboa to Prattsville, the former being the only village disturbed. No railroad was disturbed, but the construction of 12.4 miles of highways was required to replace 13.6 miles that were abandoned. As at Ashokan, the city has acquired a marginal strip around the shore line for sanitary protection of the water.

Ashokan Reservoir

The Ashokan Reservoir is located in Ulster County, about 14 miles west from the City of Kingston. Its cost, together with that of the necessary appurtenant works, including the relocation of highways and of the Ulster and Delaware Railroad, was nearly $31,500,000. This reservoir has a water surface of 8,180 acres, and an available capacity of 127,691 millions of gallons; this capacity can be increased to 130,428 m.g. by placing flashboards on the spillway. The principal structures which form this reservoir are the Olive Bridge Dam, built of masonry, across the Esopus Creek, the

The Ashokan Aerator. The building is the Ashokan screen chamber where the Catskill Aqueduct begins.

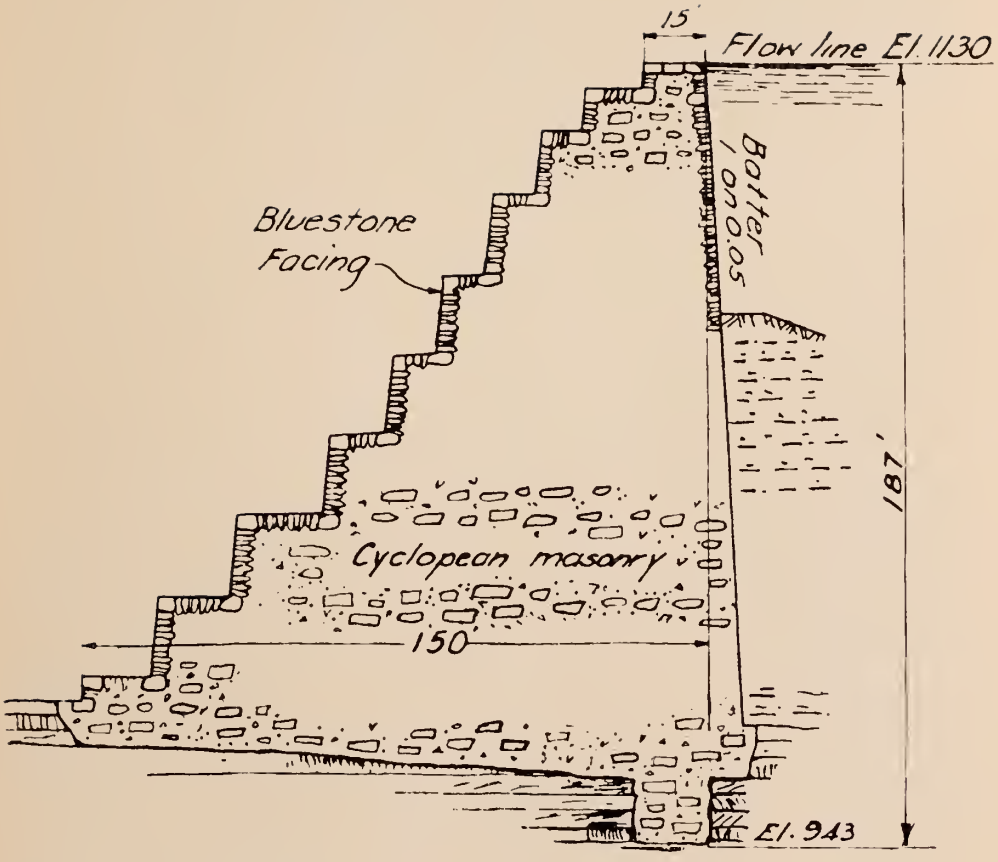
earthen dikes or dams which close in the gaps between the hills forming the natural walls of the reservoir, the dividing dike and weir, which separates the reservoir into two basins, and the waste weir, over which the surplus flood waters may be safely discharged. The Ashokan Reservoir is divided into two parts, which are known as the East Basin and the West Basin, the full water surface elevation of the West Basin being at 590 feet above mean tide at New York, while the East Basin is at an elevation three feet lower. This division into two basins was made so as to provide greater flexibility of operation and thus at all times insure the drawing of water from that part of the reservoir in which the conditions are the most favorable.

The masonry portion of the Olive Bridge Dam is founded on solid ledge-rock and was built of cyclopean concrete faced with smoothly finished concrete blocks. At each end the masonry section is flanked by earthen dikes. The bottom and slopes of the reservoir basins were cleared of trees, brush and all other objectionable matter. This work also required the construction of 40 miles of new highway, ten new bridges, one of which has a span 200 feet long, and another a total length of 1120 feet. The relocation of the Ulster and Delaware Railroad required the construction of 11 miles of new road-bed and track.

Just below the reservoir provision has been made for jetting the water into the air in fine spray, thus permitting thorough admixture of oxygen, the removal of objectionable gases and the breaking down of other matter causing tastes and odors. The aerator consists of a basin approximately 250 feet by 500 feet, containing about 1600 nozzles, through which jets of water are thrown vertically into the air.

Kensico Reservoir

The Kensico Reservoir, in Westchester County, 30 miles north from the City Hall, was designed to contain sufficient Catskill water for maintaining the supply over a period of about two months so that the flow to the City will not be interrupted while the 75 miles of aqueduct between it and the Ashokan Reservoir are at any time out of service. This reservoir is formed by the Kensico Dam, across the valley of the Bronx River, about three miles north of White Plains, and 15 miles north of the Hillview Reservoir. Its available capacity with water at spillway elevation is 29,171 million gallons. By means of permanent flashboards on the spillway the capacity has been increased to 30,573 m.g. The surface elevation at spillway is 355 feet above mean tide at New York. The area of its water surface at this elevation is 2218 acres, and the marginal protective strip around its entire circumference is in few places less than 500 feet wide. The Kensico Dam contains altogether nearly one million cubic yards of



GILBOA DAM

MAXIMUM SECTION

SCALE: 1" = 40'

Note:—Elevations refer to mean sea level at Sandy Hook.

masonry—about one-third that which the Egyptians placed in the great pyramid. At the point of greatest height, it rises 307 feet above the rock foundation on which it rests. A new highway system, rendered necessary by the construction of the Kensico Reservoir, embraced the construction of 15 miles of road on which were a number of bridges, one of them a reinforced concrete structure of five arches, each about 127 feet long. This bridge carries the highway over an arm of the reservoir and the roadway at the center is 107 feet above the reservoir bottom.

Catskill water enters the Kensico Reservoir near its upper end and is drawn from the lower end through a system of gates located in chambers about one mile north from the Kensico Dam. At this point, provision is made for controlling the rate at which the water is drawn, for screening and for sterilizing it with liquid chlorine. Here also has been provided a large aeration basin in which the water is thrown into the air through 1,599 nozzles. (This operation results in thoroughly mixing the water with air and thus aiding its purification.)

The Kensico Dam is a gravity masonry structure built of cyclopean masonry faced on its upstream side with concrete blocks and with granite masonry on its downstream face. In order to provide for the movements which result from seasonal changes of temperature, the dam is divided into sections by expansion joints spaced about 80 feet apart. Local stone was used for the facing of the dam and an effort was made to secure as rough and rugged an appearance as was consistent with the principles of the adopted design.

The Kensico Dam is located practically on the site of a small original dam which formed the old Kensico Reservoir in which were stored the waters of the Bronx and Byram Rivers. This old reservoir was very much smaller and lower than the present one, and it has been entirely obliterated.

Preliminary surveys for the Kensico Reservoir were begun in May 1906, and the contract for the construction of the dam was awarded in December 1909, the amount of the contract being $8,006,300. It was required that the work should be entirely completed by February 1920. Due, however, to the exceptional manner in which the work was prosecuted, the dam was completed to its full height nearly four years sooner than was thought possible when the contract was prepared.

Hillview Reservoir

The Hillview Reservoir is located in the City of Yonkers, just north of the New York City Line, and 15 miles south of Kensico Reservoir. It is an uncovered, artificial reservoir of the earth embankment type, and is

Schoharie Reservoir, showing flood flow discharging over spillway of Gilboa Dam.

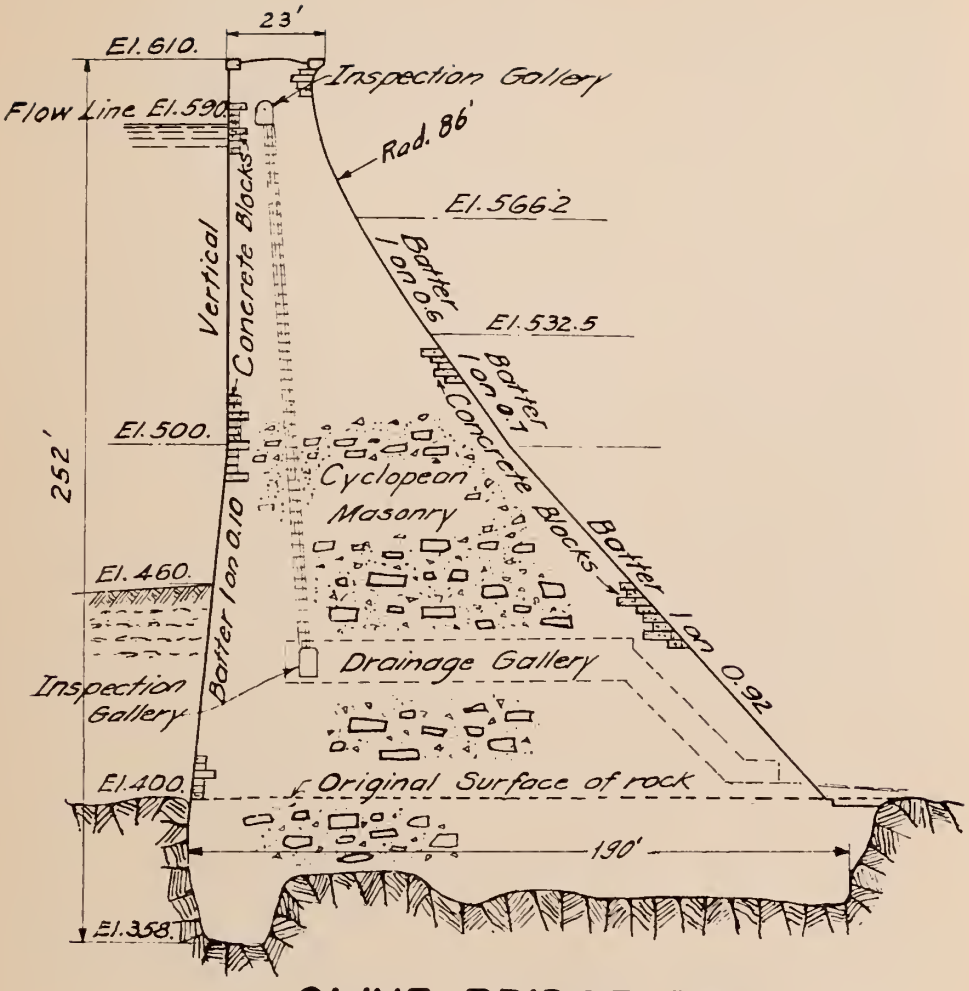
lined with concrete. It has a depth of 36½ feet and a water surface area of 90 acres. It holds 929 m.g., its function being to equalize the difference between the steady flow in the aqueduct and the use of water in the City, as it varies from hour to hour throughout the day. Its outlet is the vertical downtake shaft of the large distribution tunnel No. 1 which extends through the Bronx and Manhattan to Brooklyn with a connection to tunnel No. 2 extending through the Bronx, Queens and Brooklyn. The high pressure of the water delivered to the city through these tunnels is due to the elevation of the water surface in Hillside Reservoir, which is 295 feet above sea-level. Catskill water is delivered in the city, 161 feet higher than Croton water. The reservoir is divided into two basins by a wall 2,740 feet long that contains the bypass aqueduct, so that either one or two basins may be used, or by-passed, whenever required, directly into the city tunnels. The contract for its construction, including some tunnel work, was awarded in December 1909, the cost of the work being $3,212,900. It was first filled December 29, 1915.

Silver Lake Reservoir

This distribution reservoir for Staten Island is about 2,400 feet long by 1,500 feet wide, uncovered and formed by the natural ground and by artificial embankments with core-walls. It is not lined with concrete. A dividing dike paved with concrete divides the reservoir into two basins, holding, together, 435 m.g. From a gate chamber built in this dike reinforced concrete conduits extend to the boundary of the reservoir. Cast iron and steel pipes connect these with the Narrows siphons and with the Staten Island service mains. The reservoir has a depth of 35 feet. The water surface is 228 feet above sea level.

Catskill Aqueduct

Four distinct types of conduit or aqueduct were adopted to meet the varying physiographic features of the country traversed by the aqueduct from the Catskill mountains to the city. Where the topography and the elevation of the ground permitted, the cut-and-cover type was used. This type was the least expensive, and was built for a total of 55 miles. The construction consisted of excavating a trench, in the bottom of which a floor or invert of concrete was placed. Resting upon the sides of the invert and bonded to it, the side walls and arch of concrete, without steel reinforcement, were poured between steel forms, to the desired horse-shoe shape. From outside to outside of the masonry required a trench 28 feet wide or about as wide as between curb to curb of a New York cross-town street. Sufficient earth was taken from the trench to form a protective grassed covering of at least three feet over the concrete. That portion north of Kensico Reservoir is 17 feet high and 17 feet 6 inches wide,



OLIVE BRIDGE DAM

MAXIMUM SECTION

SCALE: 1" = 40'

Note:—Elevations refer to mean sea level at Sandy Hook.

inside dimensions, and has generally a slope of about 1.1 feet per mile, which permits a flow of some 620 m.g. without putting the aqueduct under pressure. Between Kensico and Hillview Reservoirs the cross-section was enlarged to a height of 17 feet 6 inches and a width of 18 feet.

Where hills or mountains were encountered, and it would have been impracticable or uneconomical to circumvent them, tunnels were driven and lined throughout with concrete without steel reinforcement. This, the grade-tunnel type, acts similarly to the cut-and-cover type in that the water flows in it as it would in an open channel. It also is a horse-shoe shape, but of lesser dimensions and steeper slopes. There are 24 of these grade tunnels, aggregating 14 miles; they are 17 feet high and 13 feet 4 inches wide inside.

Where valleys were encountered, it was not possible to carry the aqueduct along at the natural elevation or gradient which the water would take, and in such cases, types were adopted which would withstand the internal pressure produced by placing the aqueduct below the hydraulic gradient. In the larger valleys the pressure tunnel type was used, which consisted of a circular tunnel driven deep enough below the valley bed so that the rock would withstand the internal pressure. The tunnel is connected at either end to the aqueduct by vertical circular shafts also in suitable rock. Tunnels and shafts are lined with concrete without steel reinforcement. All seams in the rock around the concrete were filled by forcing in, under pressure, thin grout made of Portland cement, fine sand and water. Drainage shafts were constructed so that each pressure tunnel can be unwatered for inspection, cleaning and repair. Besides the end and drainage shafts other shafts were sunk to aid in excavating and lining the tunnels. These construction shafts were afterwards sealed with deep concrete plugs just above the tunnel and partially refilled, near the top, with rock debris and earth supported on concrete arches across the shaft. There are seven of these pressure tunnels, totaling 17 miles, varying in diameter from 14 feet to 16 feet 7 inches.

The most important of the valleys to be crossed was that of the Hudson River, where the tunnel was driven in granite rock at a depth of 1,114 feet below sea-level. This 14 foot tunnel extends from a shaft at Storm King Mountain on the west bank to another shaft on the east side of the river at Breakneck Mountain, a distance of 3,022 feet.

Across the smaller valleys, or where the rock was not suitable for a pressure tunnel, three parallel lines of riveted steel pipe each encased in concrete and lined with two inches of cement mortar, were laid in trenches just below the natural surface and covered with a protective grassed embankment of earth. This is known as the steel-pipe siphon type, although it is not truly a siphon but rather an inverted siphon. The pipes are from 9 to 11 feet in diameter and are made of steel plates from 7/16 to ¾ inch in thickness, riveted together. There are fourteen of these siphons, totaling six miles.

The Ashokan Reservoir showing the dividing weir dike, the Ashokan bridge and portions of the east and west basins of the reservoir.

City Tunnel No. 1

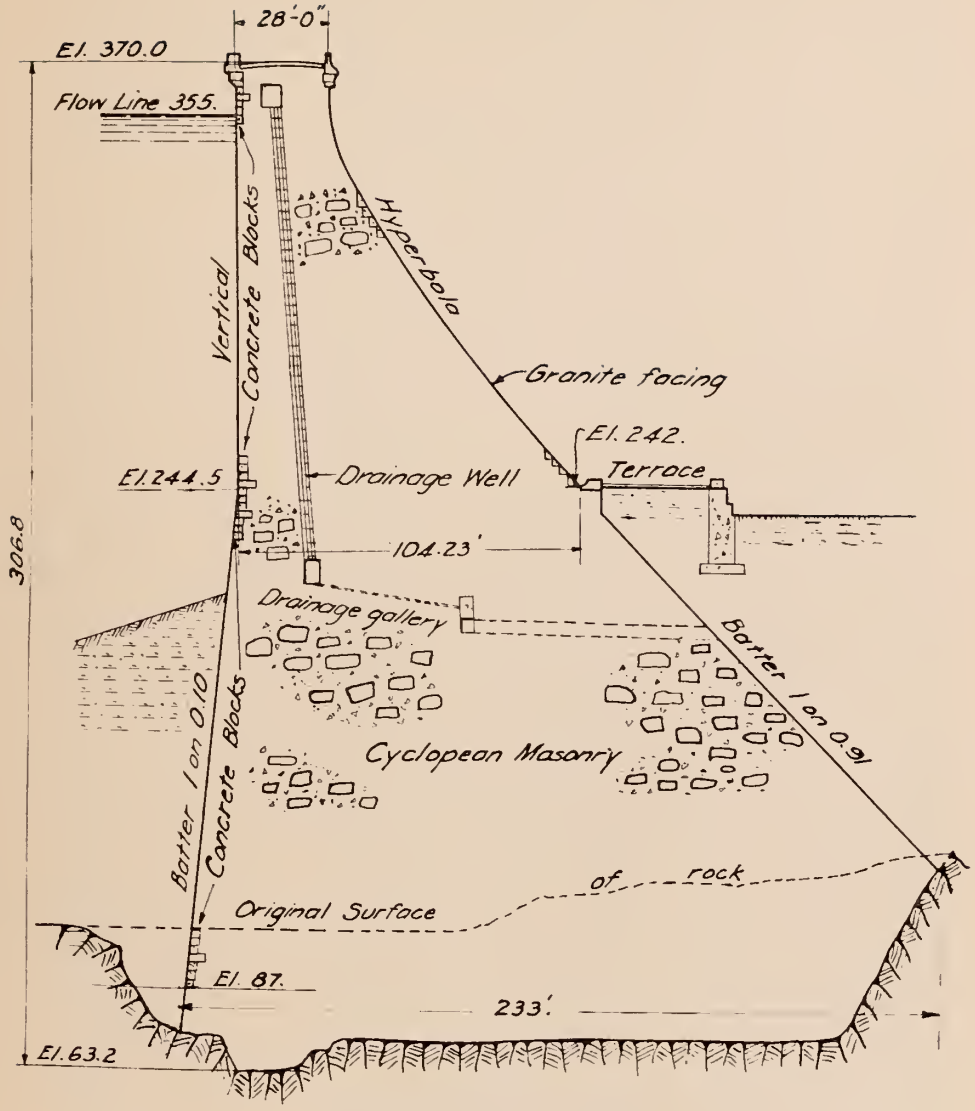
From Hillview Reservoir, Catskill water is delivered into the five boroughs by a circular tunnel in solid rock, reducing in diameter from 15 feet to 14, 13, 12 and 11 feet. The total length of the tunnel is 18 miles. From two terminal shafts in Brooklyn, steel and cast iron pipe lines extend into Queens and Richmond, respectively. Two flexible jointed cast iron pipes, one 36 inches and one 42 inches in diameter, buried in trenches in the harbor bottom, have been laid across the Narrows to the Staten Island shore, when a 48-inch cast iron pipe and a 66-inch steel pipe extend to the Silver Lake Reservoir. The tunnel is at depths of 200 to 750 feet below the street surface, thus avoiding interference with streets, buildings, subways, sewers and pipes. These depths are necessary, also, to secure a substantial rock covering to withstand the bursting pressure of the water inside, and afford the requisite watertightness. The waterway of the tunnel is lined throughout with Portland cement concrete.

City Tunnel No. 1, which is one of the longest tunnels in the world for carrying water under pressure, or for any other purpose, was constructed from 25 shafts, including the downtake shaft at Hillview Reservoir, about 4,000 feet apart, located in parks and other places where they interfered very little with traffic. Through twenty-two of these shafts the water is delivered into the street mains. These connections from the tunnel to the mains are made by means of vertical riveted steel pipes (called risers) embedded in concrete in the upper part of each shaft, and lined with concrete to prevent corrosion inside. Provision is made for unwatering the tunnel, whenever necessary, for inspection, cleaning or repairs.

Unusual features in connection with the operation of the tunnel are the bronze valves in the shafts, 48 inches and 72 inches in diameter, and the section valves, 66 inches in diameter, also of bronze. The former are located about 100 feet below the top of sound rock and are designed to close automatically in case of an important break in the valve chamber. They can also be closed by hand from within the chambers at the shaft tops. The section valves, two in number, are located across the main tunnel, at the bottom of shafts 13 and 18, and permit the tunnel to be divided into parts and drained in sections without putting it entirely out of commission.

At shaft 3, at the northerly end of Jerome Park Reservoir, connection was made to the Jerome Park Reservoir.

The cost of the portions of the Catskill Aqueduct within the city limits, including the tunnel, pipe lines, appurtenances and Silver Lake Reservoir, was $23,000,000.



KENSICO DAM

MAXIMUM SECTION

SCALE: 1" = 40'

Note:—Elevations refer to mean sea level at Sandy Hook.

City Tunnel No. 2

A second tunnel, 17 feet in internal diameter and 20 miles in length, known as City Tunnel No. 2, has recently been completed, and was placed in service March 31, 1936. It extends from Hillview Reservoir through the Bronx, under the East River at Riker's Island, through Queens and Brooklyn, to the intersection of Hicks Street and Hamilton Avenue, connecting with the first City Tunnel at Ft. Greene Park and also at State and Nevins Streets. This tunnel not only delivers additional water, but also serves to safeguard the continuity of the supply to the various boroughs and provide better regulation of service pressures under the increased demand of recent years. It cost approximately $50,000,000.

RIDGEWOOD SYSTEM

The drainage area tributary to the Ridgewood System on Long Island extends from the borough limits of Brooklyn easterly approximately to the Suffolk County Line. The watershed is bounded on the south by the marshes and tidewaters of Jamaica and Hempstead Bays, and on the north by the ground water summit which, in a general way, follows the surface divide. The area of the watershed is about 168 square miles and at present developed, including three driven well plants within the limits of the borough of Brooklyn, may be depended upon for a yield of 115 m.g.d.

The greater part of the watershed is within the broad sandy plain which slopes gently from the hills in the central part of the island southerly to tidewater. The surface soil covering is usually light and very pervious, and ordinarily overlies coarse yellow sands and gravels of glacial origin. Below these occur gray sands and gravels separated by strata of clay of varying thickness and extent which extend to bed rock at a depth of 500 to 1,100 feet or more. Due to the porous character of the soil, practically all the rainfall is absorbed and passes underground towards the sea; a small portion appears in the form of streams where the surface of the ground dips below the water table.

That part of this watershed to the west of Hempstead is generally known as the old or west watershed; the present sources of supply are Smith's Pond, Pines Pond, Hempstead Pond, Schodack Brook, Hempstead Storage Reservoir, and ten driven well pumping plants. The supply is collected by a brick conduit of horse-shoe section, about 12 miles long, having a slope of approximately six inches to the mile, extending from Hempstead Pond to the Ridgewood Pumping Station, where all the water is pumped into the Ridgewood Distributing Reservoir; a 72-inch steel pipe line extending the entire length of the watershed was formerly utilized for conveying the delivery of some of the driven well plants to the Ridge-

The Kensico Dam and portion of the reservoir, with the Kensico lower effluent chamber in right background.

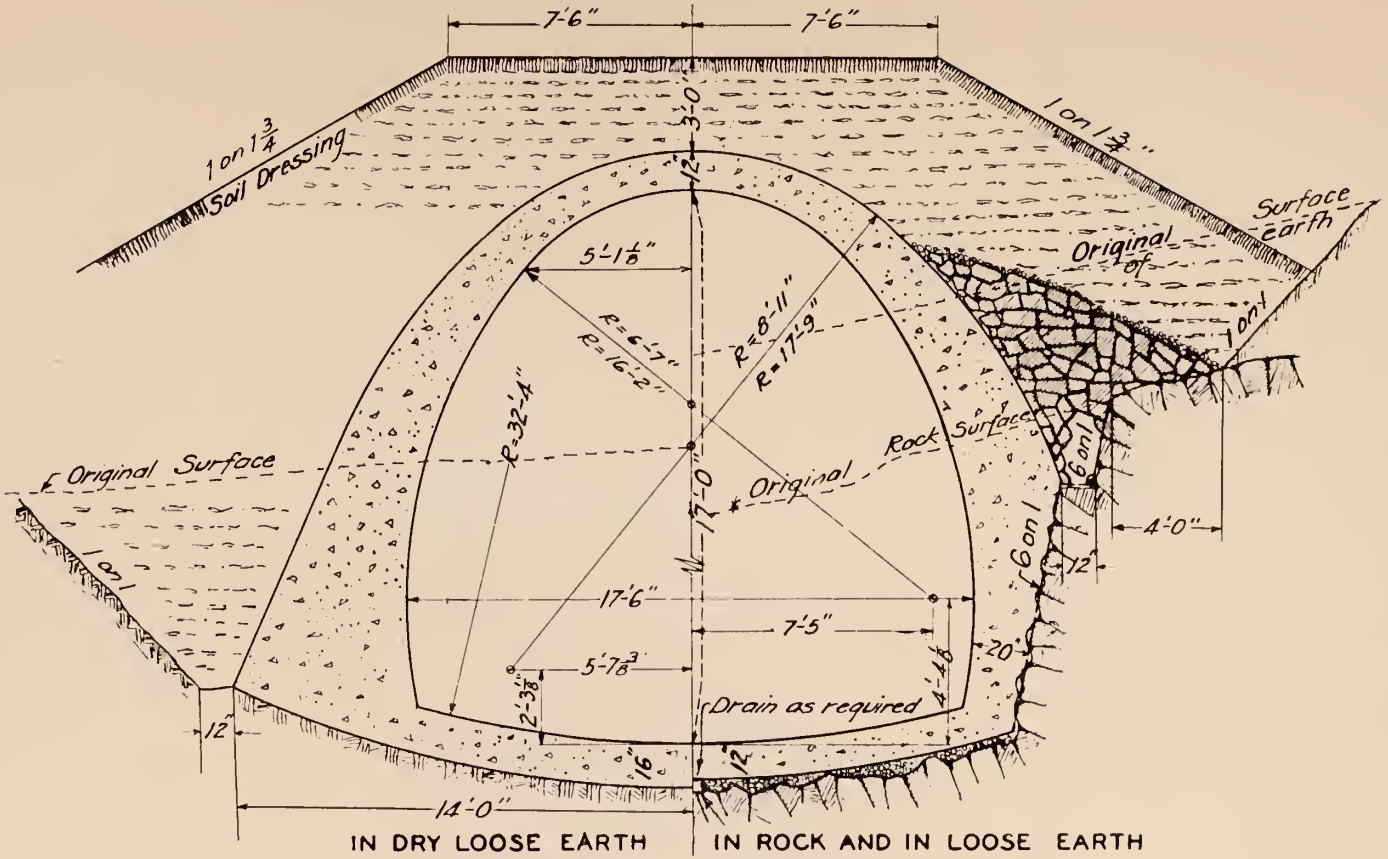
wood Pumping Station, but in 1925 the section extending westerly from the Milburn Pumping Station was placed under the Brooklyn distribution pressure, and delivered water to Brooklyn, the Rockaways and other sections of Queens Borough. The brick conduit has a gradually increasing section towards the west, the carrying capacity of the maximum section being 76 m.g.d. The other ponds on this shed (Baisley's, Springfield, Simonson's, Clear Stream, Valley Stream and Watts), the surface waters of which were originally pumped into the main conduit or delivered into same by gravity through branch brick conduits of circular cross-section, have been abandoned, on account of pollution due to increase in population.

The new watershed, adjoining the old on the east, has for its sources of supply five ponds—Milburn, East Meadow, Newbridge, Wantagh and Massapequa—five driven well plants, and two infiltration galleries. The Milburn and Newbridge Ponds have been abandoned as direct sources of supply. The supply is collected and carried by gravity to the pump well of the Milburn Pumping Station through a brick conduit a little over 7¼ miles long, extending from Massapequa westward to the Milburn Pumping Station, and having a grade of one in ten thousand.

This conduit is of horse-shoe section 5 feet, 11 inches high, and 7 feet, 4 inches wide at its easterly or Massapequa end, with a capacity of 40 m.g.d. The size increases at each supply pond and at its westerly end at Milburn Pumping Station the section is 6 feet, 11 inches high by 9 feet, 4 inches wide, with a capacity of 59 m.g.d.

The ponds in the east watershed discharge into the conduit which they immediately adjoin on the north, through short sluice-ways; the driven well and infiltration gallery pumping plants are just south of the conduit and discharge into same, or into the 72-inch steel pipe line, through short delivery mains. The two infiltration galleries aggregate six miles in length and yield 30-40 m.g.d.; they consist of vitrified tile sewer pipe laid with open joints surrounded with gravel, from 10 to 15 feet below the normal ground water level.

All the water from the east watershed is pumped at the Milburn Pumping Station where part of the supply is delivered to the 72-inch steel pipe line before mentioned, and part through three 48-inch cast iron lines leading to Ridgewood Pumping Station, where it is repumped. Two of these 48-inch lines formerly extended directly to Ridgewood Pumping Station, being reinforced at Spring Creek by another 48-inch main. In 1927 the three 48-inch pipe lines west of Spring Creek were replaced by a 72-inch reinforced concrete pipe which was made necessary by the construction of Sunrise Highway. These mains adjoin and are parallel to the old brick conduit for the entire distance west of Smith's Pond. The third 48-inch pipe from Milburn reduces to 36 inches at the efflux chamber of the aban-



IN DRY LOOSE EARTH IN ROCK AND IN LOOSE EARTH

CATSKILL AQUEDUCT

CUT AND COVER

SCALE : ¼" = 1'-0"

doned Milburn Reservoir and terminates at the old brick conduit at Smith's Pond; by this means the old conduit can be partly utilized for conveying some of the yield of the new watershed.

QUEENS SYSTEM

Local municipal sources of supply within the limits of the Borough of Queens are derived from driven wells. All of the local sources in Queens must be pumped, and the city maintains two steam and one electric pumping station, and seven individual electrically operated well stations for this purpose. The Queens System yields about 24 m.g.d. and is used, as needed, to supplement the Catskill supply.

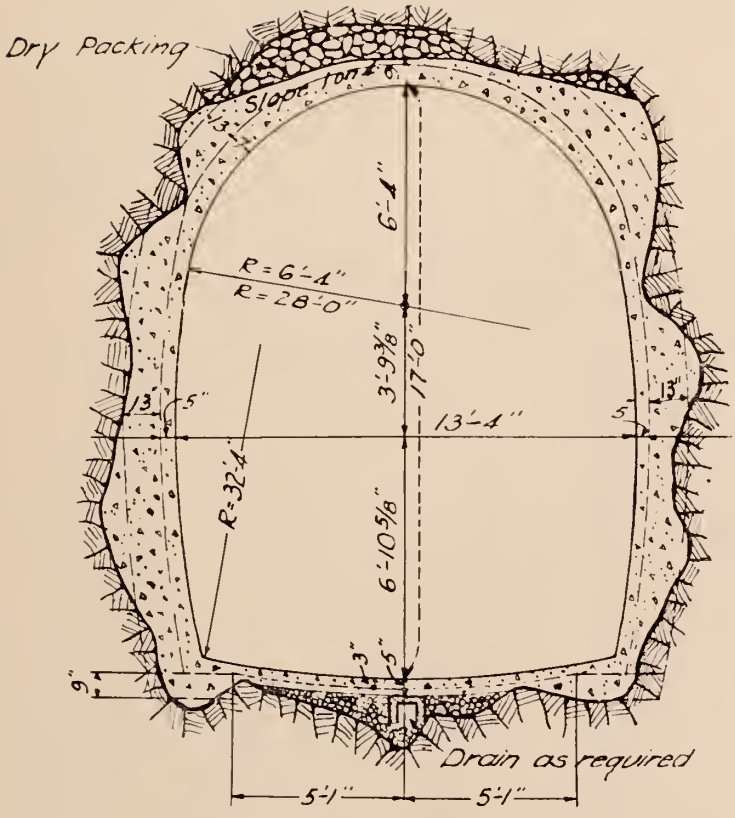
DEVELOPMENT OF ADDITIONAL SUPPLY FROM LONG ISLAND

Application was made February 23, 1932, to the State Water Power and Control Commission for developing an additional supply of 94 m.g.d. from the Long Island Watershed in the Counties of Kings, Queens and Nassau to maintain pressures locally in heavy draft periods, and to permit the substitution of Long Island waters during periods of extreme drought for a portion of the water that normally would be taken from the Catskill Watershed. Most of the wells that were to be thus developed would not have been drawn upon for the greater part of the time. In addition to the 94 m.g.d. stated above, the application also covered a proposed development of 10 m.g.d. in the Rockaways for an emergency supply.

The State Water Power and Control Commission rejected, with the exception of the Rockaway development, in almost its entirety, the application, the chief reason being the overdevelopment of the subsurface sources, particularly in the westerly portion of the island.

RICHMOND SYSTEM

The Richmond System consists of three driven well plants located in different parts of the borough. One of these plants consists of five stations driven electrically, each pumping its output into the distribution system. The Richmond System yields about 10 m.g.d. and is now being held in reserve. One station, electrically operated, is used for boosting Catskill water to the high and intermediate services.



CATSKILL AQUEDUCT

GRADE TUNNEL

SCALE: $\frac{1"}{4}$=1'-0"

UTILIZATION OF THE PRESENT SOURCES OF WATER SUPPLY

As previously stated, the city now has available, in addition to the Catskill supply, all of its older sources, including the Croton, Brooklyn, Queens and Richmond Systems.

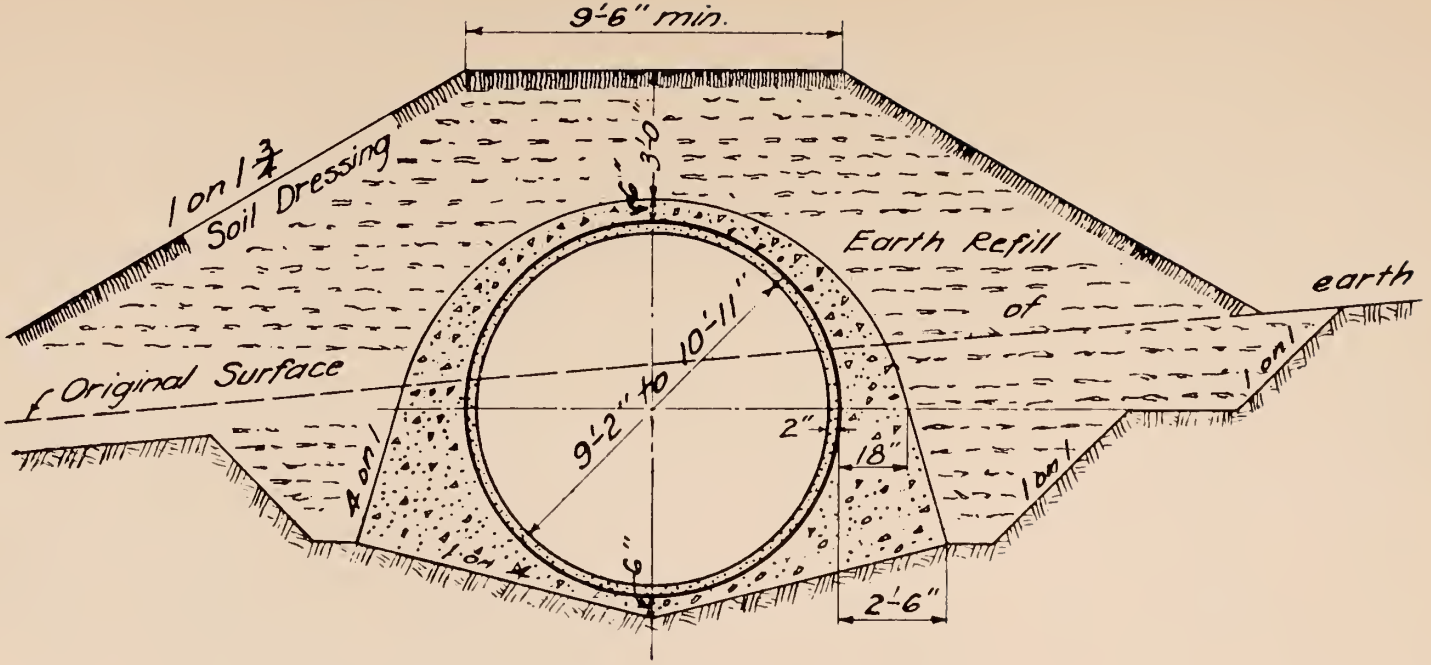
The sources of supply for the municipal system, and the amounts each may furnish are as follows:

Sources of Water Supply	Tributary watershed area Sq. Miles	Quantity estimated to be continuously available based on drought period such as might occur once in 100 years, with a reserve of 25% of total available storage.
Schoharie Watershed	314	500
Esopus Watershed	257	
Bronx & Bryam Watersheds	22	10
Croton Watershed	375	300
Ridgewood & Brooklyn Boroughs	Indeterminate	115
Queens Borough	"	24
Richmond Borough	"	10
TOTAL		959
Proposed Developments		
East Branch Watershed	370	370
Neversink Watershed	70	70
Rondout Watershed	100	100
Additional wells in Richmond	Indeterminate	10
TOTAL		550

All of the sources of supply furnish a safe and palatable water. Therefore, when it becomes necessary to furnish additional amounts of water, due to increase in consumption, the available sources are drawn upon in the order of their cost of operation.

Catskill water flows and is delivered to all five boroughs of the city by gravity, the only exception being small areas located on the higher ground. It is generally used to the full present capacity of the Catskill Aqueduct, because through its greater pressure it constitutes the least expensive of the supplies to operate.

Croton water also flows to the city by gravity, but it is delivered to the Boroughs of Manhattan and the Bronx at an elevation which is much lower than the Catskill supply, and the amount that can be used without pumping is limited to the demands in portions of Manhattan and the Bronx,



CATSKILL AQUEDUCT

STEEL PIPE SIPHON IN EARTH

THREE PIPES FOR EACH SIPHON

SCALE: $\frac{1}{4}$"=1'—0"

lying in general, below elevation 40 feet. The demand in these portions averages about 130 m.g.d. All Croton water that is used on higher ground must be pumped. The department maintains three steam and one electrically operated pumping station for this purpose, having a combined capacity of about 160 m.g.d.

The city maintains all of its old sources of supply and retains a reserve force to permit the prompt starting up of some of the stations in case of emergency. The pumped supplies, being the most expensive to use, are drawn upon as the gravity supplies are utilized to their greatest permissible extent.

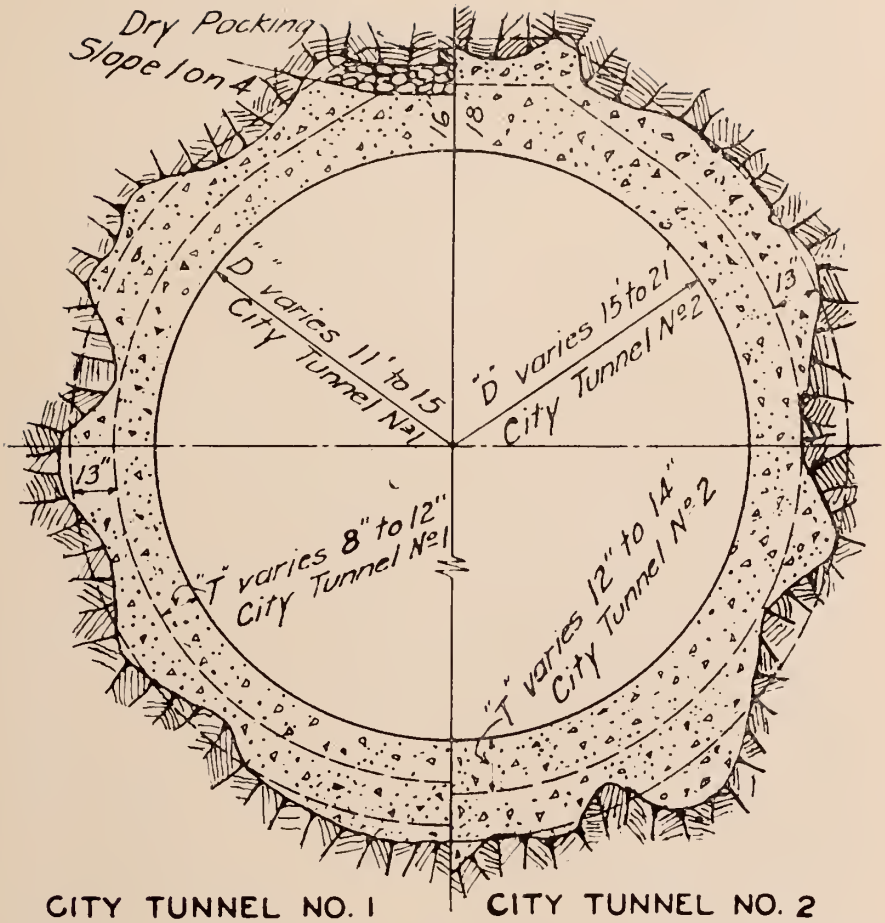
QUALITY OF THE WATER

A great safeguard which the City possesses is the extent of storage on its up-state watersheds; the long period of sedimentation afforded by the large storage reservoirs serves to reduce the bacterial content and turbidity. For the sanitary protections of these reservoirs the City acquired a marginal strip averaging 1000 feet in width around the Schoharie and Ashokan Reservoirs, 500 feet around Kensico Reservoir and 300 feet around the Croton Reservoirs and along the streams emptying into them.

An inspectional force under a sanitary expert patrols the watersheds to detect and abate sources of contamination and to see to it that the department's sanitary rules and regulations are observed.

All water is treated with chlorine. The Croton, New Aqueduct, is so treated at the Croton Lake Gatehouse, and at Dunwoodie in Yonkers, the Old Aqueduct at Dunwoodie and the 135th Street Gatehouse. On the Croton watershed the Peach Lake effluent and Tonnetta Brook are treated at Brewster, Katonah Brook at Katonah, Kisco River at Mt. Kisco, St. Mary's Brook at Bedford Hills, Kilday Brook at Bedford, the outlet of Lake Gleneida at Carmel and the sewage at the Brewster and Mt. Kisco plants. The Catskill is treated as it leaves the Ashokan Reservoir, at Kensico Reservoir and again at the Hillview Reservoir downtake chambers. The Long Island supply is treated at Milburn Pumping Station, Ridgewood Pumping Stations, Smith Pond, and the wells at Hook Creek, Clear Stream and Watts Pond. The Brooklyn, Queens and Richmond driven well stations are also chlorinated. There are altogether some 40 city-owned chlorinating plants and 80 privately operated plants at which chlorine may be applied to the water supplied to the city consumers.

A very high degree of purification has been uniformly secured at all of these plants. The typhoid fever death rate has been progressively reduced, being but 0.5 per 100,000 of population in 1936, nor were these



CITY TUNNEL NO. 1 CITY TUNNEL NO. 2

CITY TUNNELS NO. 1 & NO. 2

PRESSURE TUNNEL

SCALE: $\frac{1}{4}$" = 1'-0"

deaths due to impure water, but rather to other causes, or to disease contracted outside of the city limits.

All Catskill water is aerated to free it from gases which produce unpleasant odor or taste. These aerators, each consisting of some 1600 nozzles, are installed at the Ashokan and Kensico Reservoirs.

Microscopic organisms which develop in the reservoirs and at times impart an unpleasant taste and odor to the water, are destroyed by treatment with copper sulphate and by chlorine dosage.

To reduce the turbidity of the Catskill supply when necessary, alum and lime are added at a coagulating plant at Pleasantville, about 30 minutes flow above the influent to Kensico Reservoir; the flow entangling the turbidity, settles out in Kensico Reservoir before the water reaches the effluent gate house.

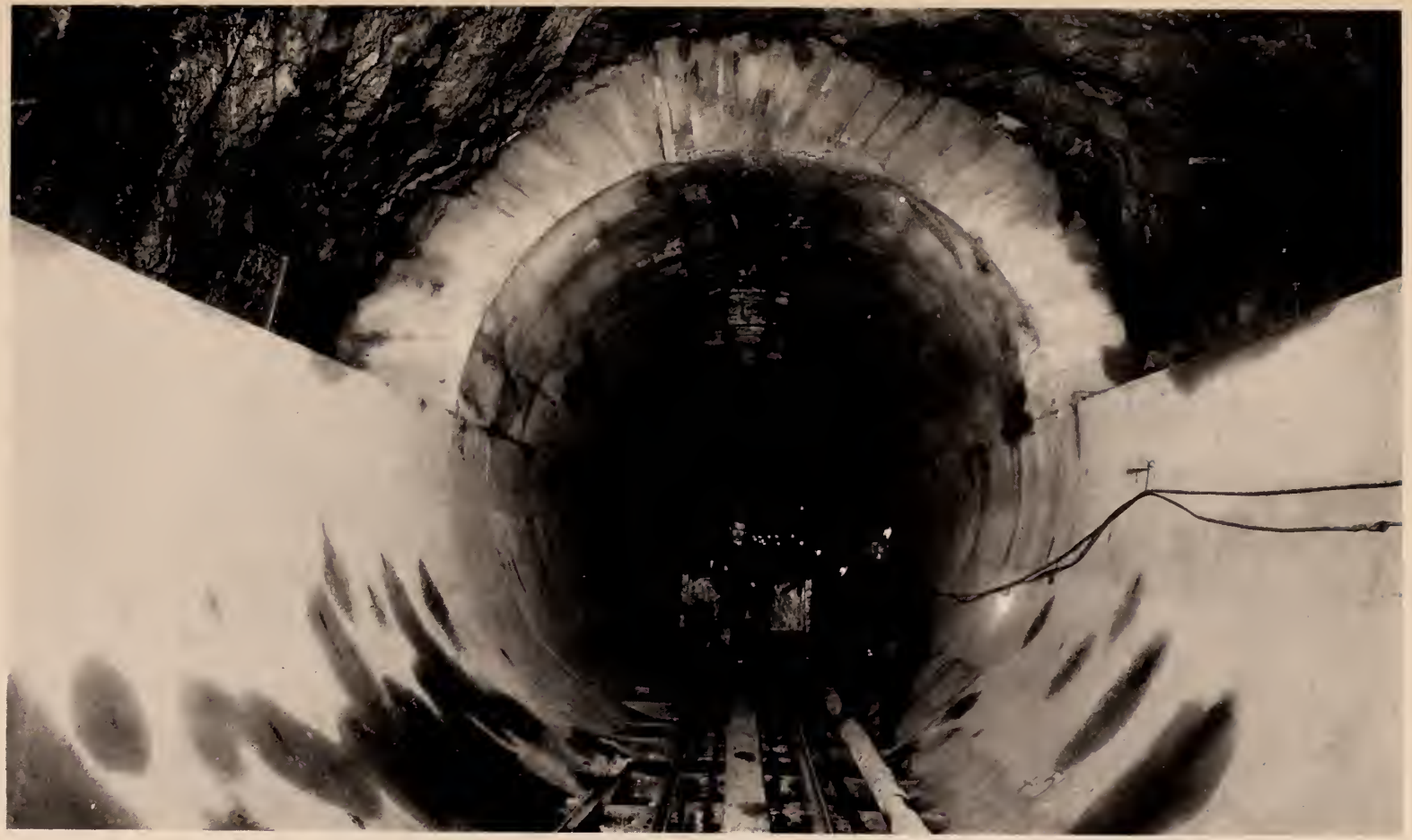
The department operates the sewage disposal plants of the village of Brewster, in Putnam County, of the village of Mt. Kisco, in Westchester County, of the villages of Chichester and Pine Hill in Ulster County, of the village of Tannersville in Greene County and of the village of Grand Gorge in Delaware County; it makes periodic tests to control the operation of the disposal plants of private institutions in the watershed and passes upon plans for all private disposal plants.

Open gravity type rapid sand filters are used to remove iron from the well waters at the Springfield, Jameco and Rockaway Park Pumping Stations and by means of pressure filters at the Flushing Station. The private companies operate two gravity and three pressure filters for iron removal from well waters.

The reforestations started in the Croton watershed in 1912 by planting three and four-year old evergreen transplants along the shores of reservoirs and adjacent to public roads has been continued in this as well as in the Catskill, Bronx and Byram watersheds. These trees in addition to beautifying the general landscape, provide a dust screen, prevent erosion and serve to equalize the run-off.

New mains are sterilized and are not placed into service until laboratory analyses show them to be clean. Cross-connections, or connections from any other source of supply to any piping supplied by city water, are forbidden.

At three laboratories, daily bacteriological examinations are made of samples of water taken at different points. Additional samples from sources of supply which do not require daily investigation result in the laboratories examining over 26,000 samples during the year. In case any portion of the supply is shown to be unsatisfactory, either its use is discontinued, or



City Tunnel No. 2, 17 feet in diameter, during construction, showing the concrete lining, with the arch still to be placed in the foreground.

the objectionable conditions are ascertained and remedied. The laboratories in question are well equipped with modern apparatus and are located respectively, at Mount Prospect Reservoir, Brooklyn, at Mount Kisco, Croton watershed, and at the Ashokan gatehouse, Catskill watershed.

The question whether or not the water supply of New York City should be filtered was considered in 1910, the then responsible authorities reaching the conclusion that it was not necessary to do so at that time. With the growth of the communities on the watersheds and under an insistent public demand the subject will, in due course, undoubtedly again receive attention.

DISTRIBUTION SYSTEMS

The distribution systems in the various boroughs are divided into independent services or zones, with three or more such zones in each borough. The areas of these zones are determined chiefly by the local topography. The ground elevation in the city varies from a few feet above sea level along the water front to 430 feet at Todt Hill in the Borough of Richmond; this, incidentally, is the highest point on the Atlantic coast south of Maine. The highest ground elevations in the other boroughs are: Manhattan, 267 feet; Bronx, 284 feet, Brooklyn, 210 feet, and Queens, 266 feet above tide.

The average pressure at hydrants in the different service zones in the city ranges from 35 pounds per square inch in the Manhattan low service to 80 pounds per square inch in the Richmond high service area. The average pressure in the city is approximately 55 pounds per square inch, which is adequate for supplying water to the top floor of an eight story building.

To provide for the hourly fluctuations in demand, the maximum hourly rate during the morning and evening hours being two to three times that shortly after midnight, as well as a limited amount of storage within the city limits to meet emergencies, there are five principal distributing reservoirs. The Hillview Reservoir just north of the city line and the Silver Lake Reservoir in the Borough of Richmond have been described under the "Catskill System."

Jerome Park Reservoir in the Borough of the Bronx is an uncovered concrete lined basin formed by earthen embankments and natural ground, excepting the easterly side which is a masonry structure originally intended for a division wall to divide the reservoir into the east and west basin, the former never have been built. The "division wall" carries the Old Croton Aqueduct throughout its entire length as well as a branch of the New Croton Aqueduct to its southerly end where it discharges into the reservoir. The main new Croton Aqueduct crosses the reservoir in a tunnel about

100 feet below the surface and continues to the 135th Street gatehouse in Manhattan. The flow into and out of the reservoir is controlled by three gate chambers.

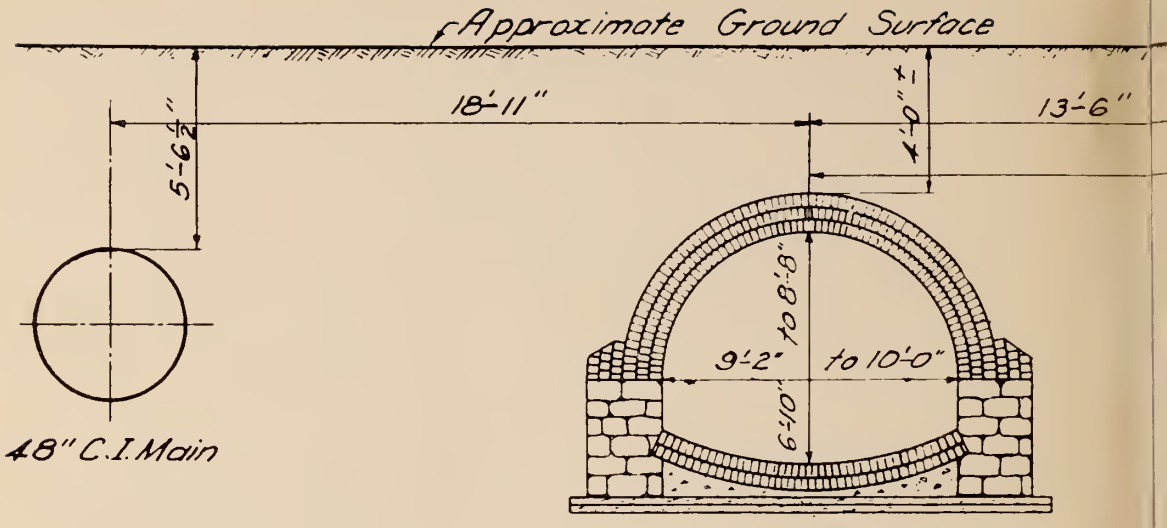
The gatehouse at the northerly end of the reservoir at the division wall controls the flow through a short stretch of tunnel leading to Shaft 3 of City Tunnel No. 1 of the Catskill System. The arrangement of piping in the chamber permits either the delivery of Catskill water into the reservoir or the pumping of Croton water from the Reservoir into City Tunnel No. 1. This pumping is by means of three electrically driven pumps at the so-called Mosholu Pumping Station, installed in the shaft chamber, each pump of a capacity of 20 m.g.d.

The present reservoir with a capacity of approximately 800 m.g.d. at the spillway elevation of 135.50 feet was filled in 1905. Work at the east basin was suspended pending decision of the question of filtering the Croton supply. The filtration plant was to have occupied the area intended for the east basin but in 1912 the entire project was abandoned and the lands were released by the department in 1917. The site is now occupied by educational buildings, subway yard and other structures.

The new Central Park Reservoir in Manhattan is an open basin completed in 1862 when the Old Croton Aqueduct was the only aqueduct supplying water to the City of New York. It was constructed "to keep an available supply of water in case a break should occur in the aqueduct making it necessary to shut off the water for examination and repairs." At the present time it still receives water from the Old Croton Aqueduct and in addition it is supplied from the New Croton Aqueduct by means of 3—48 in. pipe lines from the 135th Street gatehouse. The reservoir is now being used as an equalizing and distributing reservoir for the low service areas in Manhattan; it holds 1021 million gallons at the spillway elevation of 119.36 feet.

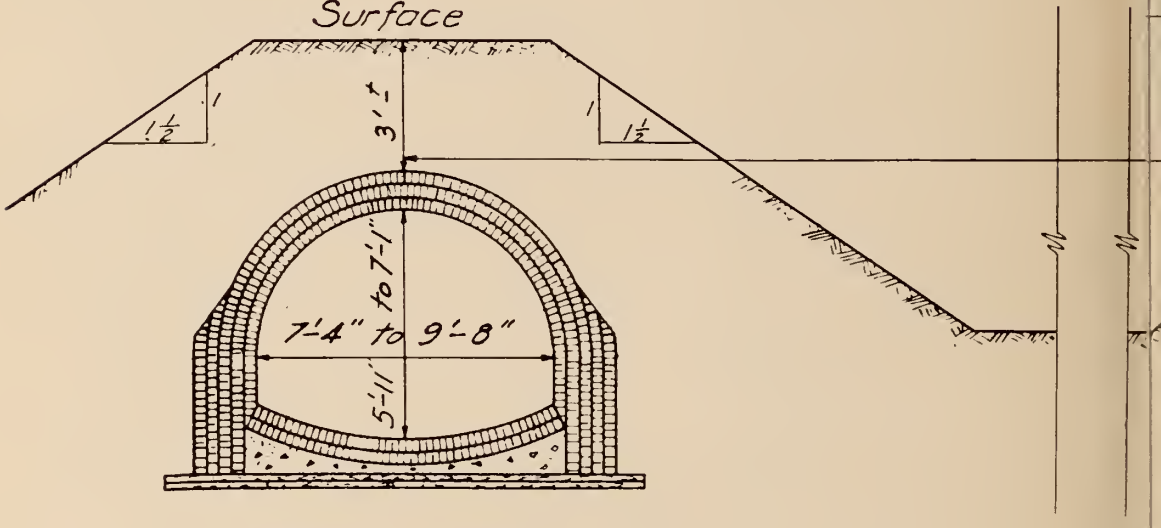
The entire supply of Croton water delivered to the city through the Croton Aqueducts is distributed from Jerome Park Reservoir in the Bronx and from Central Park Reservoir and the 135th Street gatehouse in Manhattan. A number of widely scattered areas of low elevation, generally below 40 feet, are supplied by gravity from these distributing points. This gravity supply amounts to about one-half of the total available Croton supply; the remainder of the Croton supply is pumped at the 89th Street and the 179th Street Pumping Stations in Manhattan and at the Mosholu and Jerome Avenue Pumping Stations in the Bronx to reach the higher elevations.

The Catskill supply, which extends to all five boroughs, is distributed from the riser shafts of City Tunnels No. 1 and No. 2. The Catskill gradients are sufficiently high to reach all but the highest elevations in Man-



MASONRY CONDUIT

APPROXIMATE LIMITS: SPRING CRE

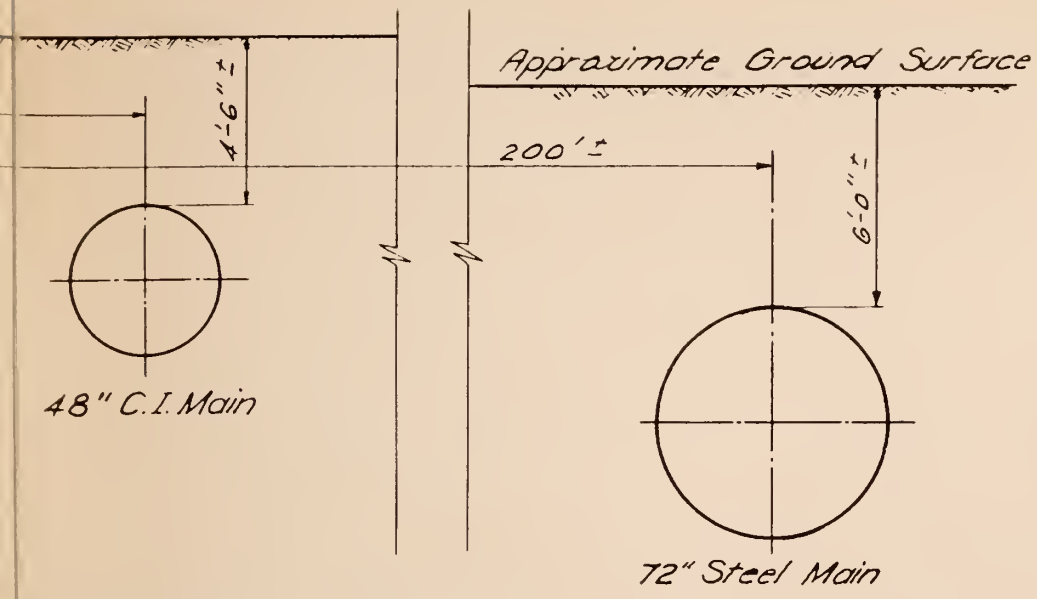


MASONRY CONDUIT

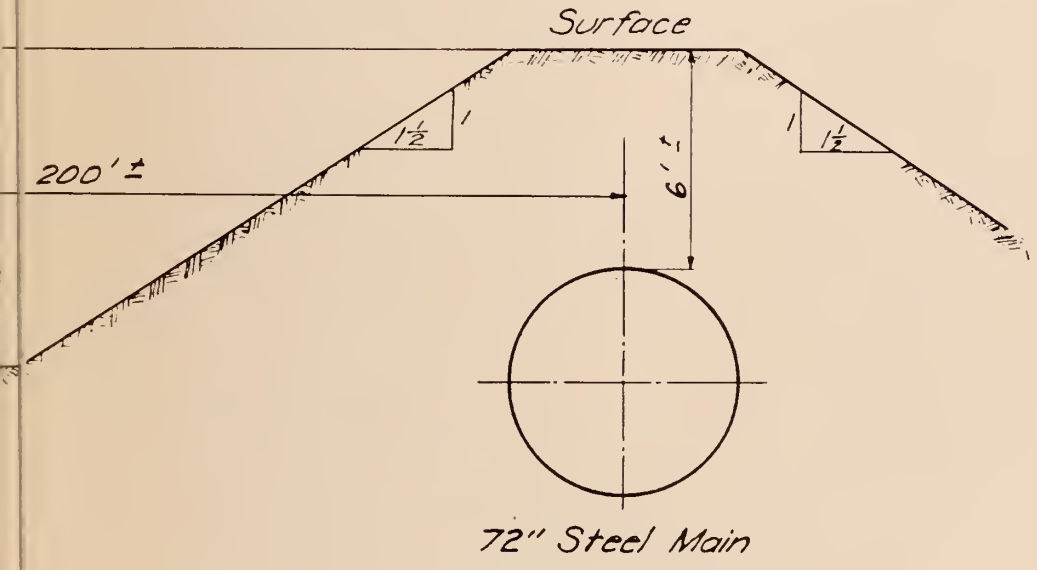
APPROXIMATE LIMITS: MILLBURN PUM

BROOKLYN CONDUIT

SCALE: ¼"



E. TO MILLBURN PUMP. STA.



STA. TO SUFFOLK CO. LINE

ND PIPE LINES

- 0"

hattan and Richmond. The pressures are regulated at the distributing points, if necessary, to maintain the desired pressures in the different service zones. In the services supplied with both Catskill and water pumped from some other source of supply, the Catskill pressure is regulated to accommodate the gradient of the pumped supply.

The supplies from the Ridgewood, Brooklyn and Queens Borough systems which are obtained chiefly from sub-surface sources, must be pumped. Part of the supply is delivered directly into the Ridgewood Reservoir, which also receives water from the Catskill System and is used as an equalizing reservoir for the Brooklyn low service. This reservoir, located on Cypress Hills, consists of three basins with an aggregate capacity of 304 million gallons at the high water elevation of 172.54 feet. Each basin has a puddle bottom and sloping sides paved with stones. The first two basins of half the total capacity were completed in 1858 and the third in 1891.

The pipes used in the City for distributing the water supply range in size from 4 inches to 72 inches. At the close of 1936 the total length of steel and cast iron pipe in service amounted to 4,690 miles as given in detail in one of the attached tables. With the improved protecting coatings developed, the department adopted, in 1926, in order to reduce the considerable damage from floods resulting from breaks in cast iron trunk mains, the policy of installing water mains 30-inch and larger of steel with a minimum thickness of plate of ½ inch.

The minimum size of cast iron pipe used for extensions is 12″ in congested sections and 8″ elsewhere. To overcome the excessive tuberculation caused by the soft and "active" Catskill water, all cast iron pipe since 1929 has been furnished with an ⅛″ interior cement mortar lining coated with a cold application of asphalt paint (without effect either upon the taste or odor of the water) to retard or entirely prevent the leaching of the cement.

Gate valves are located near street intersections and the arrangement provides in general for convenient shut-off sections.

A standard double-disc valve, opening clockwise, adopted some 25 years ago, predominates. The valves in the Catskill shafts are operated by small water motors; some of the large control valves in the gatehouses of the distributing reservoirs are motor or hydraulically operated. At the close of 1935, a total of 125,816 valves, ranging in size from 4″ to 48″ were in use.

Hydrants are of the double nozzle type, and most of the 72,070 in use at the end of 1936 were the New York standard, which has a 6″ gated connection with the main and a 7½″ barrel with one 2½″ and one 4½″ outlet.

Fifteen repair companies are maintained for keeping the valves and hydrants in good operating condition, to repair breaks in water mains, and stop reported leaks such as may be caused by loose joints, abandoned taps, service pipes, hydrants, and valves. During the past ten years, an average of over 20,000 leaks in the distribution system were stopped annually by these repair companies. In each borough, an emergency force of, at least, one gang is on duty at all hours.

The department is authorized by statute to determine the locations not only of water mains, but of all other sub-surface structures (such as electrical conduits, gas mains, steam pipes, and pneumatic tubes) except sewers and rapid transit tunnels. This enables the department to provide for ready access to water mains for repairs and connections, to protect the water mains from excessive loads of other structures crossing them, and to ensure the reservation of adequate space for the installation of future mains.

HIGH PRESSURE FIRE SERVICE

The Department of Water Supply, Gas and Electricity also operates in portions of Manhattan and Brooklyn and at Coney Island a special service by means of a High Pressure Fire System to which no connections to buildings are permitted and which is used exclusively for fire fighting purposes.

The Manhattan system was first used in July 1908. It covers approximately 3700 acres in lower Manhattan, where it protects the valuable business and industrial centers. The Brooklyn system, which was placed in service in November 1908, protects the important manufacturing, business and water front section lying between 39th Street and the Navy Yard, covering approximately 3100 acres. The Coney Island system covers 608 acres.

One of the Manhattan pumping stations is at Oliver and South Streets and the other at Gansevoort and West Streets, each with a capacity of 18,000 gallons per minute at 300 lbs. per sq. inch, with increased capacities at lower pressures. There are two similar stations in Brooklyn, located respectively at Furman and Joralemon Streets and at Willoughby and St. Edwards Streets, the former having a capacity of 15,000 g.p.m. and the latter 9,000 g.p.m. at 300 lbs. pressure per sq. inch. The Coney Island station is at Neptune Avenue and West 25th Street; the capacity of this station is 13,500 g.p.m. at 200 lbs. pressure per sq. inch.

The length of the high pressure fire service mains in Manhattan is 128 miles, 8″ to 24″ in diameter, and in Brooklyn, 50 miles, 8″ to 20″ in diameter. The lower east side of the Manhattan System is arranged so

that it may be divided instantaneously into two independent systems; when so divided, each system serves the alternate cross streets and the alternate streets running north and south. In case of a break only one system would be affected, as the other would be shut off from it immediately by valves electrically operated from the pumping stations.

The high pressure fire service stations are operated through high-voltage current furnished in Manhattan by the New York Edison Company and in Brooklyn proper and the Coney Island Station, by the Edison Electric Illuminating Company. Upon the request of the Fire Department, the pressure can be increased up to 300 pounds per square inch. At Coney Island, the limit of pressure will be 200 pounds per square inch. When an alarm is received, pressure is furnished throughout each of the systems within the period of a minute.

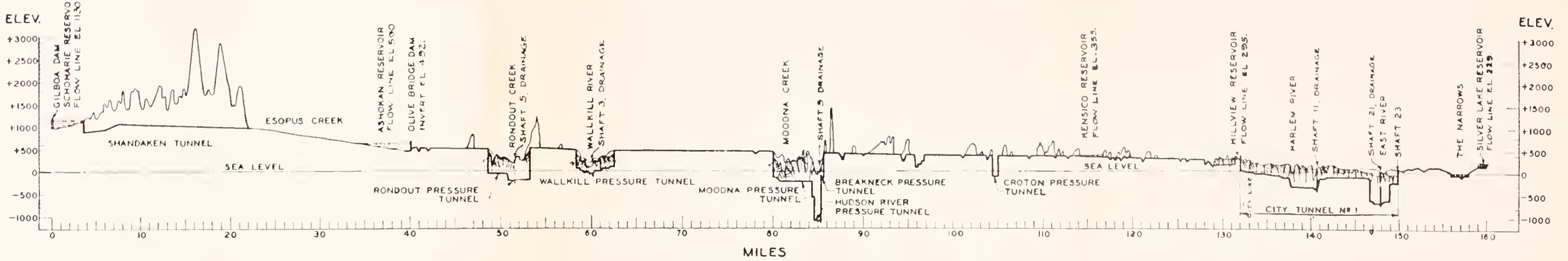
Salt water can be used in this system, but its use is not contemplated in Manhattan or Brooklyn, unless the fresh water supply were to fail, which has never yet occurred. At Coney Island, salt water is used in conjunction with fresh water.

CONSUMPTION AND WASTE OF WATER

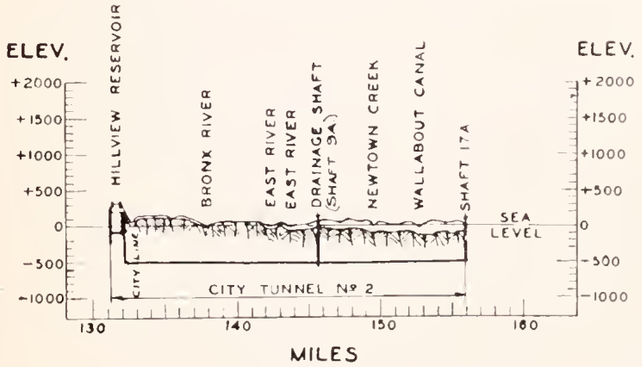
The daily aggregate consumption of water within greater New York averaged 972.5 m.g.d. during 1936, including the 59.4 m.g.d. furnished by the private water companies of Brooklyn and Queens. This corresponded to a per capita consumption of 127.1 gallons per day. In addition to the foregoing, the municipality supplied 19.5 m.g.d. to communities outside of the city.

For the last twenty years the Water Department has maintained a force of trained men under engineering supervision to trace the source of water flows entering basements, electric conduits, subways, etc., in the most difficult cases where the shop repair forces were unable to locate the source of trouble. This force operated in the Boroughs of Manhattan and the Bronx, where rock fill exists under many streets through which water from leaks readily escapes. The average leakage located and stopped yearly has been approximately 10 m.g.d. From the experience of this force, it has been known that many leaks exist that are not causing complaint and are not observable, but during the years of plentiful supply, the force (consisting since 1918 of but four field parties to cover the two boroughs) was insufficient to do more than take care of such complaint work.

The drought of 1930 brought the total available supply far below the average of previous years, uncomfortably close to the 930,000,000 gallons



PROFILE OF CATSKILL AQUEDUCT AND CITY TUNNEL NO. 1



CITY TUNNEL NO. 2

SCALE:- HOR. - 1 INCH = 8 MILES
VERT. - 1 INCH = 1600 FEET

per day average consumption of that year, and forcibly emphasized the necessity for utilizing all possible measures for rapid reduction of waste and conservation of the supply.

During 1930, an additional force of four field parties was approved to make systematic surveys and searches for those hidden underground leaks that are not causing complaint. This work was confined to the Boroughs of Manhattan and the Bronx, where the sub-surface conditions as described are most favorable to the accumulation of such leakage.

In 1931, this special force covered those two boroughs with a "Preliminary Survey" aiming to locate as rapidly as possible the largest leaks of this character, and during the year, stopped leakage totaling 26,000,000 gallons a day. The regular complaint force during the same period stopped, in addition, a total leakage of 14,000,000 gallons per day.

In 1932, the special force was employed on a "re-survey" including tests on the individual house service pipes to locate the smaller main and service leaks. The total leakage stopped was 25,000,000 gallons per day. The cost of the underground waste work is estimated at $3.00 per million gallons of water saved, which is only a small fraction of the cost of delivering water to the city. The work has been continued to the present time with the same successful results.

In addition to the surveys for the suppression of leakage from underground mains and service pipes, a house-to-house survey for the suppression of leakage from plumbing fixtures in some 580,000 unmetered buildings was started in the Spring of 1934 with a corps of 270 Temporary Emergency Relief Administration employees. The aggregate waste within buildings where the services are not metered is conceded to be a very large amount. On the first survey made by these employees, about 80% of the unmetered buildings were examined. Out of a total of 12,500,000 fixtures examined, 400,000 were found leaking. It is estimated that in 1935 a reduction of 50 m.g.d. was effected and that by repeated inspections covering the city once a year, it might be possible to reduce the consumption 90 m.g.d. A new and better qualified force of inspectors furnished by the U. S. Works Progress Administration was organized the latter part of 1935, and continued this work to June, 1937. On this second survey, in addition to reporting leaky fixtures, the force reported the different items upon which frontage rates are based, such as the number of stories, families, baths, etc., in order to check and revise, if necessary, the annual frontage charges. On this second survey, all reports of leaky fixtures were followed up to see that they were promptly repaired by the owners of the property, and if they were not repaired, a penalty of $2.00 was imposed each time subsequent inspections showed the fixture or fixtures still leaking. The penalty becomes a lien upon the property. It is expected to continue this work with regular City employees.

PRIVATE WATER COMPANIES

Some 750,000 citizens residing in Brooklyn and Queens and consuming about 60 m.g.d. are still dependent upon private water companies for water. All of these companies draw their supplies from driven wells. The one located within the Borough of Brooklyn is the New York Water Service Corporation (Flatbush Plant), serving the Twenty-Ninth Ward (Flatbush). In the Borough of Queens, the Jamaica Water Supply Company and the New York Water Service Corporation (Woodhaven Plant) furnish water for the Fourth Ward. The Broad Channel Corporation, which formerly supplied a small amount of water from local driven wells to Broad Channel Island, is now being supplied from the municipal system. The Flatbush Water Works, which originally supplied the Twenty-ninth Ward of Brooklyn, and which was succeeded in 1926 by the N. Y. W. Service Corporation, was originally incorporated February 14, 1881, and has an exclusive franchise for supplying that territory with water. The Woodhaven Water Supply Company, which supplied the Woodhaven or westerly section of the Fourth Ward of Queens, and was succeeded in 1926 by the N. Y. W. Service Corporation, was incorporated February 28, 1888. The Jamaica Water Supply Company, which supplies the easterly portion of the Fourth Ward of Queens, was incorporated April 21, 1887.

The average quantity of water supplied by the private water companies during 1936 was as follows:

New York Water Service Corp. (Flatbush Plant)	26.3	m.g.d.
Jamaica Water Supply Co.	25 3	"
New York Water Service Corp. (Woodhaven Plant)	7.8	"
Broad Channel Corp.	0	"
TOTAL	59.4	m.g.d.

The private companies, except as to rates, are under the general superintendence, regulation and control of the Commissioner of Water Supply, Gas and Electricity.

SUPPLY TO COMMUNITIES OUTSIDE OF NEW YORK CITY

Under Chapter 726 of the Laws of 1905 "Any village or town in the county of Putnam, or a corporation or person or persons authorized by or in pursuance of law to establish therein a water works system for supplying such village or town and the inhabitants thereof with water, may con-

nect its or their water mains and pipes with the lakes, streams, reservoirs, aqueducts, water pipes and conduits of the City of New York now or hereafter located in such county and take water therefrom for supplying such village or town and the inhabitants thereof with water." The amount is limited by the population supplied and the per capita consumption of New York City; the price is to be agreed upon with the Board of Estimate and Apportionment of New York City or fixed by the Supreme Court upon application by such applications.

Chapter 350 of the Laws of 1909 granted similar rights to municipalities in Nassau County, at prices to be fixed by the Commissioner of Water Supply, Gas and Electricity which, however, were not to exceed the Brooklyn rates.

Under Chapter 601, Laws of 1916, similar privileges were granted in the County of Westchester to municipal corporations, and at New York City rates. Application need only be made to the Commissioner of Water Supply, Gas and Electricity.

Under Chapter 525 of the Laws of 1928, it is lawful for any of the municipal corporations or water districts in the Counties of Ulster, Greene, Delaware, Schoharie, Sullivan, Orange, Westchester and Putnam, to take and receive from any of the reservoirs, aqueducts, conduits, streams or pipes of the City of New York, a supply of water for the uses and purposes of said municipal corporation or water district authorities or, upon application by either party, by the State Water Power and Control Commission. Rates are to be based upon the actual cost to the City of New York after deducting fixed and operating charges upon the distribution and delivery system within the city limits; such charges are not to exceed the New York City rates and are subject to review by the Supreme Court. Up to December 1, 1938, these charges have been fixed at 75 cents per 1000 cubic feet of Catskill water and 50 cents per 1000 cubic feet of Croton water.

Quite a large number of communities have taken advantage of these privileges for securing their entire supply or to augment their supply in period of emergency.

Sing Sing Prison in the village of Ossining is furnished with a supply of Croton water through a connection to the Old Croton Aqueduct at Spring Street under an Act of Legislature in 1861 (Chapter 282); the price paid the city is 2½c per 100 cubic feet.

The total amount of water supplied in 1935 to these outside communities and institutions averaged 19.5 m.g.d.

WATER REVENUE

The city's water revenue is established through what is known as the Bureau of Water Register. The functions of the Bureau consist in the establishment of revenues from the service, sale, or use of water, and of miscellaneous charges arising therefrom.

In addition, the Bureau supervises the work incidental to the installation of meters, prevention of unnecessary waste of water, and has general supervision over the use of water.

Charges for water on an annual basis, meter registry, costs for installation and repair of meters, and the expense of providing meter glasses are duly transmitted to the Bureau of City Collections, Department of Finance, for rendering of the necessary bills. Such charges are now collected by said Bureau.

Charges for unmetered water furnished in connection with the erection or alteration of buildings require that a permit be obtained and payment made therefor on the basis of the quantity of water to be used as figured from plans on file in the Bureau of Buildings. Where water has been used without permit having been obtained, bills are rendered by the Bureau of Water Register, and if not paid by the end of the month succeeding that in which the bills are rendered, are transmitted to the Bureau of City Collections for entry on their records and collection thereof.

The collections at present made by the Bureau, acting as the representative of the Bureau of City Collections, represent charges for unmetered water used in the erection or alteration of buildings, use of water by vessels which take water from the various shipping hydrants, the use of water for washing street, sidewalk, areaway, step, building, or other place or thing where the regular hose permit is applied for and payment made at the rate of $7.50 per season, and water used by contractors engaged in street repairs, paving, building of sewers, subways and other public works.

Further miscellaneous revenues are established and collected by the Bureau from the following sources: insertion of taps and plugs in water mains, shutting off taps, locating taps, meter testing, fire flow test, sale of ashes, sale of grass, sale of old material, repairs to lampposts, pole licenses and rentals, electricians' licenses, subpoena feed, rental for use of city property, inspection of material, and such other miscellaneous income as might arise in connection with the activities of the department.

All water charges are established by joint action of the Board of Aldermen (under the new charter by the Board of Estimate and Apportionment) and the Commissioner of this Department.

At the close of 1936, there were 586,791 accounts, of which 421,808 were what are known as frontage, and 164,983 as meter accounts. It is estimated that about 26 per cent of the water supply to the City is metered.

Frontage rates vary from $6 for a one-story building 16 feet wide to $21 for a one-story building 50 feet wide. To these rates, $3 is added for each 10 feet in excess of 50 feet frontage and $1.50 for each story above the first. The primary frontage rate is predicated upon the building being occupied by one family, containing one bath and one water closet. For each additional bath, $4.50 per annum is added; for each additional water closet $3 per annum and for each additional apartment or family $1.50 per annum.

The above constitutes the major portion of the revenues derived on an annual basis. There are other miscellaneous charges which contribute only a small portion of the frontage revenue.

Under existing laws the Commissioner of the Department has authority to cause water meters to be installed in business premises only. The law, however, gives the owner of a lot or premises the right to apply for a meter. At present substantially all water used for commercial and industrial purposes is metered.

Meter rates are 15 cents per 100 cubic feet.

The so-called frontage and most of the miscellaneous rates, as originally established in the City of New York, remained unchanged from 1851 to the end of 1933. The meter rates remained the same from 1870 to the end of 1933. Beginning January 1, 1934, all rates were increased a flat 50%.

FINANCIAL

The Municipal Water Supply System of the entire city represents up to January 1, 1937, an investment of $519,614,000. The bonds outstanding on the same date amounted to $377,379,408.10. The cost of operation and maintenance of the system during 1936 was $7,436,242.52. Interest and sinking fund charges amount to approximately $19,775,248.80. The total revenue from the sale of water in 1936 amounted to $37,416,171.06.

ADMINISTRATIVE OFFICERS

JOSEPH GOODMAN.....*Commissioner of Water Supply, Gas and Electricity*
JOHN E. EASTMOND.....*Deputy Commissioner, Borough of Brooklyn*
HERMAN FORSTER.....*Deputy Commissioner, Borough of The Bronx*
WILLIAM H. CORREALE.....*Deputy Commissioner, Borough of Queens*
CHARLES G. KEUTGEN.....*Deputy Commissioner, Borough of Richmond*

Distribution Mains in Use at the End of 1936

	Diameter Inches	Length
Steel	72	88,194
	66	55,637
	60	63,132
	48	135,357
	36	45,357
	30	27,376
	24	686
	20	2,634
	12	3,085
	10	190
	8	985
	6	215
	Total Feet	422,848
Cast Iron	60	3,910
	48	564,027
	42	12,874
	36	443,636
	30	267,998
	24	250,244
	20	1,361,343
	16	669,926
	14	37,066
	12	5,102,113
	10	157,444
	8	8,358,078
	6	6,675,962
	4	436,352
	Total Feet	24,340,773
Galvanized W. Iron	3	25,895
	2½	10,360
	2	287,980
	1½	5,983
	1	1,823
	-¾	3,340
	Total Feet	335,381
GRAND TOTAL—FEET		25,099,002
GRAND TOTAL—MILES		4,753.59

Storage Reservoirs in Watersheds

Name	Year first placed in service	*Elevation of spillway feet	Storage with flashboards million gallons
CATSKILL WATERSHED			
Ashokan	1915	East Basin 587 West Basin 590	130,428
Kensico	1915	357	30,573
Schoharie	1926	1,130	19,583
CROTON WATERSHED			
Boyd's Corners	1873	580	1,696
Middle Branch	1878	371	4,145
East Branch	1891	416	5,243
Bog Brook	1891	416	4,400
West Branch	1895	502	10,427
Amawalk	1897	399	7,070
Croton Falls	1911	309	14,839
Croton Falls Diverting	1911	309	888
Titicus	1893	324	7,599
Cross River	1908	329	10,923
Muscoot	1905	199	5,705
New Croton	1905	201	28,110
Lake Mahopac	1870	659	575
Lake Kirk	1870	582	565
Lake Gleneida	1870	504	165
Lake Gilead	1870	496	380
Barrett's Pond	1870	778	170
White Pond	1896	830	200
Total			103,100
BRONX AND BRYAM WATERSHEDS			
Bryam	1897	451	925
Wampus	1897	409	87
Total			1,012
LONG ISLAND WATERSHEDS			
Hempstead	1879	30	880
Ponds—Hempstead	1862	....	27
Pines	1862	....	9
Smiths	1873	....	42
East Meadow	1892	....	19
Wantagh	1892	....	44
Massapequa	1891	....	17
Total			1,038

*Elevations refer to mean sea level at Sandy Hook.

Description	Limits	Type	Lgth. Miles	Rated Capacity M.G.D.
Catskill Aqueduct (Shandaken Tunnel)	Schoharie Reservoir to Ashokan Reservoir	Grade Tunnel	18	650
Catskill Aqueduct	Ashokan Reservoir to Hillview Reservoir	Cut-and-cover	55	600
		Grade Tunnel	14	
		Pressure Tunnel	17	
		Steel pipe siphon	6	
Catskill Aqueduct (City Tunnel No. 1)	Hillview Res. to Manh., Bx. & Bklyn.	Pressure Tunnel	18	1000
Catskill Aqueduct (City Tunnel No. 2)	Hillview Res. to Bx., Queens & Bklyn.	Pressure Tunnel	20	1000
New Croton Aqueduct	Old Croton Dam to 135th St. Gatehouse	Grade Tunnel	22.5	285*
		Cut-and-cover	1.1	
		Pressure Tunnel	7	
Old Croton Aqueduct	New Croton Dam to Central Park Reservoir	Cut-and-cover	33	90**
		Grade Tunnel	2	
		C. I. & Steel pipe	3	
Bronx Pipe Line	Kensico Res. to W'msbridge Res.	Cast Iron pipe	15.2	20
Long Island Brick Conduits	Massapequa Pond to Milburn Pumping Station	Cut-and-cover	7.3	59
	Hempstead Pond to Spring Creek	Cut-and-cover	12.4	76
Long Island 72-inch Steel Pipe	Suffolk Co. Line to Pitkin Avenue, Brooklyn		23.4	57
Long Island 2-48″ Pipe Lines	Milburn P. S. to Spring Creek		14	50
Long Island Cast Iron Pipes	Milburn P. S. to Old Milburn Res. Efflux. (48″)		1.6	25
	Old Milburn Res. Efflux. to Smith's Pond (36″)		1.4	14
	Spring Creek to Ridgewood P. S. (60″)		0.6	25
	Pitkin Avenue, B'klyn, to Ridgewood P. S. (48″)		0.7	25

*South of Jerome Park Reservoir 250 m.g.d.
**Because of needed repairs present capacity limited to 45 m.g.d.

Distribution Reservoirs and Standpipes

Borough	Name	Normal Water level elev. feet	Storage Million Gallons
	*Hillview Reservoir	295	929
Manhattan	Central Park Reservoir	119	1021
	High Bridge Standpipe	336	.....
Bronx	Jerome Park Reservoir	134	773
	Jerome Avenue Standpipe	317	.....
Brooklyn	Ridgewood Reservoir (3 basins)	172	300
	Mt. Prospect Reservoir	200	19
Queens Municipal	Flushing Standpipe	221	0.8
	College Point Standpipe	192	0.9
Richmond	Silver Lake Reservoir	229	438
	Clove Reservoir	258	2.5
	Grimes Hill Standpipe	450	0.2
	Tottenville Standpipe	151	0.1

*North of City Line.

POPULATION AND CONSUMPTION OF WATER IN NEW YORK CITY

PER CAPITA CONSUMPTION EXPRESSED IN GALLONS DAILY; OTHER FIGURES IN MILLION GALLONS DAILY

CITY							
		CONSUMPTON				Supplied by City to Communities Outside of City	Total Cons. Municipal Source
Year	Population	Mun.	Priv. Co's.	Total	Per Capita		
1898	3,272,418	325.0	23.1	348.1	106.4	Not	325.4
1899	3,356,722	349.7	24.0	373.7	111.3		350.1
1900	3,446,042	370.4	22.0	392.4	113.9	tabu-	370.8
1901	3,554,079	376.5	23.6	400.1	112.6		376.9
1902	3,665,825	387.1	25.1	412.2	112.4	lated.	387.5
1903	3,781,423	397.6	25.7	423.3	111.9		398.0
1904	3,901,023	421.2	27.9	449.1	115.1	Prob-	421.6
1905	4,025.742	444.4	29.0	473.4	117.6		444.8
1906	4,166,556	461.8	33.4	495.2	118.9	ably	462.2
1907	4,314,237	477.4	35.6	513.0	118.9		477.8
1908	4,469,248	480.0	38.6	518.6	116.0	did	480.4
1909	4,632,078	480.6	32.1	512.7	110.7		481.0
1910	4,785,190	495.6	32.9	528.5	110.4	not	496.0
1911	4,873.069	461.2	33.2	494.4	101.5		461.6
1912	4,960,948	469.4	35.6	505.0	101.8	exceed	469.8
1913	5,048,827	463.6	35.5	499.1	98.9		464.0
1914	5,136,706	507.5	36.9	544.4	106.0	0.4	507.9
1915	5,224,585	494.6	33.6	528.2	101.1		495.0
1916	5,312,464	526.9	39.3	566.2	106.6	M.G.D.	527.3
1917	5,400,343	545.0	39.6	584.6	108.3	1.0±	546.0
1918	5,488,222	616.0	43.2	659.2	120.1	3.0±	619.0
1919	5,576,101	618.9	41.3	660.2	118.4	0.6±	619.5
1920	5,683,765	689.9	45.0	734.9	129.3	0.4	690.3
1921	5,811,549	684.7	46.6	731.3	125.8	0.7	685.4
1922	5,939,333	703.3	39.2	742.5	125.0	0.6	703.9
1923	6,067,117	723.3	38.3	761.6	125.5	4.1	727.4
1924	6,195,251	738.3	41.9	780.2	125.9	4.0	742.3
1925	6,323,035	794.4	45.2	839 6	132.8	6.7	801.1
1926	6,450,819	814.5	48.8	863.3	133.8	9.0	823.5
1927	6,578,603	816.6	51.5	868.1	132.0	8.0	824.6
1928	6,706,737	825.2	52.6	877.8	130.9	10.7	835.9
1929	6,834,521	883.5	60.2	943.7	138.1	19.0	902.5
1930	6,962,305	920.8	64.5	985.3	141.5	21.5	942.3
1931	7,077,000	883.4	57.2	940.6	132.9	20.6	904.0
1932	7,192,000	877.6	58.1	935.7	130.1	21.7	899.3
1933	7,306,000	880.7	57.8	938.5	128.5	16.8	897.5
1934	7,421,000	902.2	58.5	960.7	129.5	17.0	919.2
1935	7,536,000	891.6	58.5	950.1	126.1	19.3	910.9
1936	7,650,000	913.1	59.4	972.5	127.1	19.5	932.6